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HEMORRHAGIC OSTEOMYELITIS.
(GIANT-CELL SARCOMA, GIANT-CELL TUMOR.)

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The term *hemorrhagic osteomyelitis* was first used about ten years ago to denote and describe a lesion in bone that had up to that time been considered a malignant neoplastic process.

During this period of almost a decade, a profound change in the point of view of the profession as a whole, appears to have taken place regarding the proper classification of this important pathologic structure. This change in mental attitude is to be found more particularly among those whose studies and experience have been along the lines of bone pathology and surgical therapeusis.

Fig. 1. Hemorrhagic osteomyelitis, upper end of femur before operation.

It is now better recognized that malignancy is not a feature or characteristic of the osseous pathologic process that has for a long time been diagnosed as giant-cell sarcoma and, more recently, giant-cell tumor. These terms are, however, still being commonly used to denote and describe the lesion. This is unfortunate because the process carries all the criteria, in both its gross and histopathologic aspects, of an inflammatory affection.

Such designations should be discontinued; they are inadequate, inexact, confusing, misleading, and in fact misnomers.

The conclusions reached by many of our foremost pathologists in relation to the scavenger or foreign-body type of giant-cell encountered in these lesions, absolves the cells from having any function in the rôle of tumor formation. In attempting to reach a decision whether a process in bone should be considered either neoplastic or inflammatory, from the microscopist's angle of investigation, one must disregard the giant-cell content. Such cells are the known accompaniment both of inflammations and neoplastic disease; their presence, therefore, cannot be affirmative of tumor growth. This is true only of the scavenger or foreign-body type of giant-cell.

Fig. 2. The same case, following operation. The cavity has been filled out with bone shavings.

The true tumor giant-cells present quite a different histopathologic picture, that should not be confused with the scavenger forms. They are infrequently found in bone sarcomata; when encountered they denote extreme malignancy.

For a number of years I have endeavored to keep before the profession the fact that these bone affec-

tions commonly termed giant-cell sarcomata are really not neoplasms, but definite inflammations; they are always hemorrhagic in type, non-suppurative, and chronic in character.

One cannot question the possibility that, in rare instances, a neoplastic process may arise in primary granulation tissue. Particularly is this understandable where the effort at complete repair and restoration of a structure has been unsuccessful. If, however, such neoplastic degenerative change should occur, the known characteristics of malignancy become readily observed in a microscopic picture, presenting mitotic figures, aplasia, and cellular invasion of a special type of tissue. When such histopathologic features of malignancy and autonomous growth are absent, there appears to be no justification for terming a lesion sarcomatous. The term "giant-cell tumor" seems to be equally inexact as a designation for these inflammatory processes.

Fig. 3. The same case. Result 6 years after operation.

The consensus of opinion today is against crediting giant-cells of the scavenger or foreign-body type with the power of tumor formation. On the other hand, it is quite well recognized that they do act as scavengers in performing the function of removal of sterile débris. This appears to be their only action.

It has been suggested quite recently that these bone lesions should be looked upon as borderline cases; that is, betwen an inflammation and a neoplasm.

In my opinion present methods of investigation are ample to permit us to decide definitely whether a lesion is inflammatory or neoplastic.

The picture practically always observed in the primary stage or phase of the affection termed *hemorrhagic osteomyelitis* exhibits all the factors covering our modern conception of granulating tissue structure, both in its cellular or histologic make-up and in its gross or naked-eye appearance.

Early efforts at repair in any non-suppurative area of osteolysis exhibits a picture similar to the process termed hemorrhagic osteomyelitis, giant-cell sarcoma, or giant-cell tumor. The same type of hemorrrhagic granulation tissue structure is beautifully illustrated in early efforts at repair in fractures in bone; also exactly the same tissue structure may be brought forth experimentally, in suitable operations upon normal bone, or in soft tissues.

Fig. 4. Hemorrhagic osteomyelitis. Small lesion in lower end of tibia in patient 7 years of age.

These facts should have weight against a diagnosis of neoplasm.

Recently published text-books on surgery and pathology, and numerous clinical discussions and medical papers bearing upon the subject appear quite generally to accept the inflammatory character of these processes in contradistinction to neoplastic growth.

The solitary lesion has been seen and studied by me in all bones of the body exclusive of the skull, clavicles, scapulae and manubrium.

Thus far only one case with multiple lesions in several bones giving anatomic proof of a hemorrhagic osteomyelitis has been personally studied.

In my observation the lower extremities have been the sites of the lesion in the proportion of about 3 to 1, compared with the rest of the body.

In 40 personally observed patients suffering with hemorrhagic osteomyelitis twenty-eight of the lesions were in the lower extremities, distributed as follows:

Metatarsals	1 case
Os calcis	2 cases
Tibia	11 cases
Fibula	2 cases
Femur	12 cases
Total	28 cases

Of the total 28 cases 20 were in males and 8 in females. The oldest patient in the series was 63 years, the youngest 18 months.

Six lesions in the femur were in the lower end, and six were in the upper end. The youngest patient with lesion in the upper end was 4 years, the oldest 19 years. The youngest patient with lesion in the lower end of the femur was 3½ years and the oldest 63 years. Eight of the patients in this group of 12 were males and 4 females.

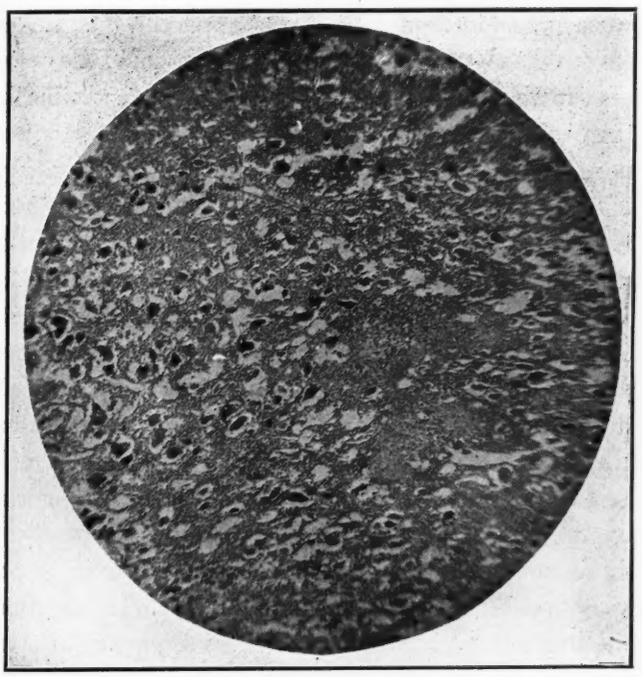

Fig. 5. Hemorrhagic osteomyelitis. Photomicrograph, low power. Tissue removed from upper end of femur in a patient 17 years old.

The smallest lesion found in the femur was the size of an ordinary cherry, the largest the size of a big orange.

Of the 11 cases in the tibia 8 were in males and 3 in females; 10 presented lesions in the lower end and 1 in the upper end.

It is interesting to note that up to the present I have encountered only one lesion involving the upper end of the tibia in a child. I have seen several cases in consultation where the upper end of the tibia in adults has been involved, but thus far there has been only one case observed in a child 10 years of age. The youngest patient in this group was 18 months old, the oldest 39 years.

The smallest lesion found in the tibia was the size of a large coffee bean, the largest the size of a baseball.

Two cases in the fibula were in the upper end, one in a female 20 years of age, and one in a male 24 years old.

The two cases in the os calcis were both males; one was 18 years old and the other 47 years.

Twenty-seven cases exhibited some degree of disability, from slight limp to distinct lameness. Limitation of motion was generally more marked in lesions near the hip joint than in those near the knee or ankle. In practically all cases one could elicit a history of recent or ancient trauma.

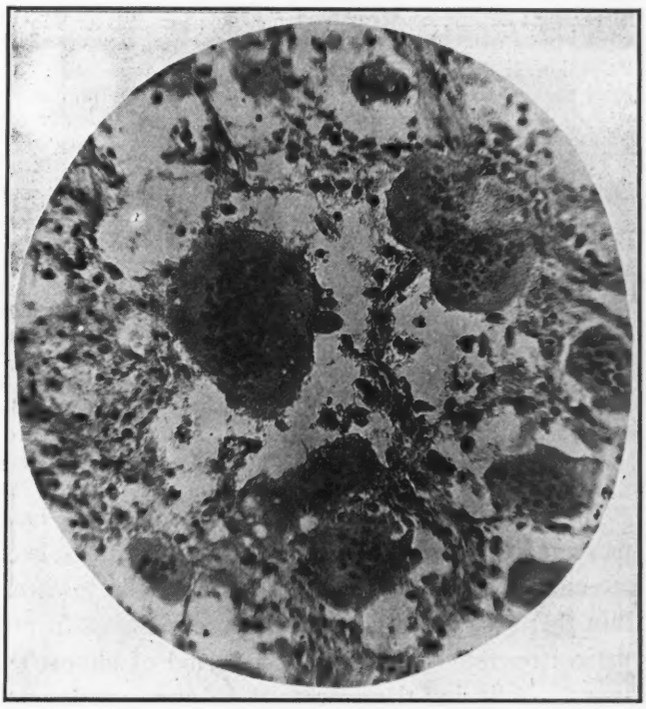

Fig. 6. Photomicrograph, high power, showing typical scavenger giant-cells, constantly present in lesions containing areas of ancient hemorrhage.

In all the 27 cases a localized area of pain could be demonstrated on pressure over lesion.

One case was accidentally discovered in the lower end of the tibia. This patient was without symptoms. Deep pressure over the site of the area of osteolysis exhibited by roentgenogram elicited pain. Joint motion in the ankle was normal.

It may be definitely stated that a preliminary diagnosis is impossible without the use of the *x*-ray. It should also be emphasized that an area of osteolysis exhibited by the *x*-ray may mean one of many other gross pathologic lesions. At times it may be necessary to combine the clinical and *x*-ray pictures with

the gross and microscopic studies, to make a positive diagnosis of hemorrhagic osteomyelitis. As a rule, however, a carefully studied clinical picture with the information conveyed by the roentgenogram is sufficient for a correct diagnosis.

The following table covers the more important features pertaining to the solitary lesion in making a diagnosis of hemorrhagic osteomyelitis:

Clinical Picture	
Age of Patient.....	May occur at any age. Most frequent in first and second decades of life.
Duration of Lesion.	Months—perhaps years before lesion attains large size.
Symptom of onset..	Usually history of injury, recent or remote.
Pain.....	Apparently never constant.
Inspection.....	Usually some enlargement at site of lesion.
Palpation.....	Tenderness and pain on pressure.
Joint movements ...	Some limitation of motion in nearest joint. Limp with lesion in lower extremity.
X-ray Pathology	
Cancelli.....	Area of osteolysis rather clear cut, rounded or oval in shape.
Periosteum.....	Usually intact unless lesion has attained large size, years after onset.
Gross Pathology...	Appearance of vascular granulation tissue sometimes interspersed with areas of fibrosis, or degenerated hyaline masses.
Microscopic Picture.	Heterogeneous cellular picture of fibroblasts, scavenger giant-cells. endothelial and polynuclear leucocytes, lymphocytes, eosinophiles and red blood cells.

In only one instance in this series of cases have more radical operative measures than curettage been attempted. Insofar as it has been possible to ascertain there has been no recurrence of disease in any patient operated upon during a period of almost ten years. Believing the process to be purely inflammatory in nature, following curetting, we have avoided using chemical destructive agents in the cleaned out cavity. On the contrary, in order to increase stimulation, and promote the effort of healthy granulations, that may finally become bone and bring full anatomic restoration of tissue, swabbing with tincture of iodine has been used as a routine. Perhaps the swabbing is unnecessary. Depending upon the size of a cavity or space left following curetting, one's judgment comes into play, whether or not to fill in with bone shavings, chips or bone graft. Any lesion smaller than a pigeon's egg needs no filling.

Successful end-results are the final factors that appeal to both patient and surgeon following treatment of cases. When such may usually be attained safely by minor surgical measures there can be no justification for radical and mutilating operations sometimes performed when these lesions are falsely stigmatized "sarcomata."

THE INJECTION OF OXYGEN INTO JOINTS FOR DIAGNOSIS.

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About two years ago, at a local medical society, Drs. Arthur Stein and William H. Stewart of New York City, presented roentgen-ray pictures of patients into whose peritoneal cavities oxygen had been injected. The pictures showed very clearly the outlines and positions of the solid organs and peritoneal adhesions, and the method they described appeared likely to prove a great aid in diagnosis. The areas occupied by the oxygen were very light, and the usually ill-defined shadows of the abdominal organs were much intensified. It was apparent that under favorable circumstances this method could be used also in the study of soft tissues not recognizable in the ordinary roentgenograms. The practice of intraperitoneal injection of oxygen and roentgenography had been used previously, and has been greatly extended recently in the study of subdiaphragmatic, pelvic and other intraabdominal conditions. In joints it had been used to only a very limited extent, and without particularly encouraging results. There are many joint conditions in the study of which additional aid is needed; and it was hoped that the intraarticular injection of oxygen might help to differentiate the various types of internal derangement of the knee, and be of value in doubtful cases of loose semilunar cartilages, resistant chronic synovitis and other joint lesions. I felt, therefore, that the method ought to be given a trial, particularly as it had been used without any ill-effects.

A search of the literature showed that about 10 years ago oxygen had been injected into joints by French and German surgeons, but there was no clear record of the technic employed, the effects on the joints, or the results accomplished. Recently I found an article by a French military surgeon who injected oxygen for therapeutic purposes into the knees of five cases of hydrarthrosis and hemarthrosis with excellent results. At the last meeting of the American Medical Association in Boston, Sir Robert Jones told me that he had injected oxygen into the joints of 40 patients about 20 years ago. He had employed about the same method that I used, with satisfactory results. After several experimental injections into the joints, I found that the injection when performed under aseptic precautions was not accompanied by any untoward effects. The animals and their joints were apparently normal a few minutes after the injection. I therefore deter-

mined to use it in the joints of human beings, and shall briefly relate my experiences in a few of the cases.

CASE I. Mrs. W. Following an injury, her left knee became painful and swollen and she walked at times with a limp. There was no history of locking. When I saw her in 1919 the knee was swollen, there was no local heat, and tenderness was present at the joint line anteriorly, sometimes on the inner side and sometimes on the outer. The motions were somewhat painful and very slightly restricted. There was some crepitus on motion. Roentgen-ray pictures were negative. She had apparently some internal derangement of the knee with possible injury to the semilunar cartilages. The diagnosis was not

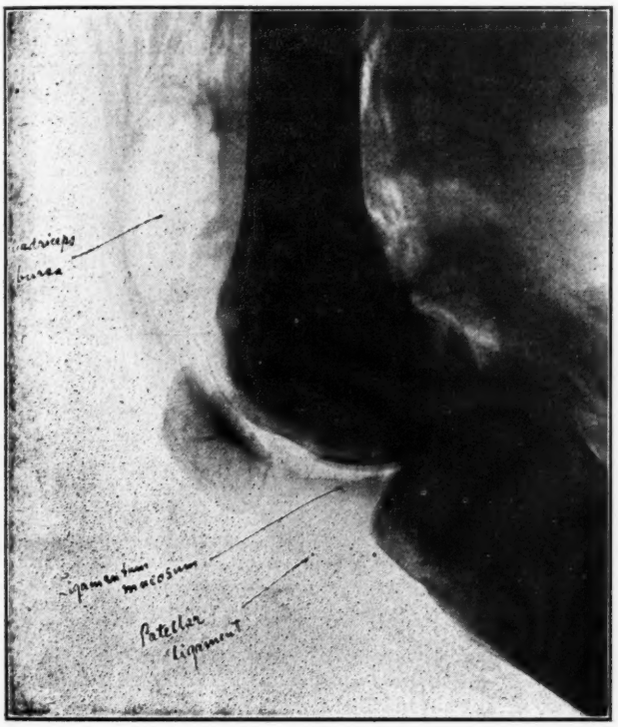

Fig. 1. Case 1. F. W. Chronic synovitis, possible loose internal semilunar cartilage. Lateral view after oxygen injection. Note distension of joint with oxygen and also oxygen in intermuscular planes.

clear and the case seemed an appropriate one for the use of oxygen.

On Nov. 24, 1919, I made my first trial of the method in the following manner. The patient's limb was prepared as if for an operation and she was taken into the operating room. The skin over the knee was painted with tincture of iodin, a small square just above and external to the patella was anesthetized with novocain, and a needle about 2½ inches long was inserted into the quadriceps bursa. The barrel of an ordinary hypodermatic syringe was then attached to the needle and a sterile tube connected the oxygen tank with the syringe barrel. A moderate amount of gas, sufficient to produce an evident distension, was allowed to enter the joint. The needle was withdrawn and a dressing was applied. The patient was then taken to the *x*-ray laboratory. By the time she got there some of the oxygen had escaped. The knee was *x*-rayed and the pictures compared with those taken before the injection. The second group of pictures showed oxygen in the cul-de-sac, but in no other part of the knee. Five days later the knee was again injected. This time the needle was inserted just below and external to the patella and without anesthetizing the skin. The injection was made in the *x*-ray laboratory so that as little as possible of the gas would be lost before the pictures were taken. Roentgenograms (figures 1 and 2) showed that the gas had entered the knee-joint proper and had also distended the cul-de-sac. Some of the gas escaped into the subcutaneous tissue and into the intermuscular planes. Slight pain was felt during the injection, but none afterward. The gas disappeared in 36 hours, but the patient was kept in bed 3 days be-

Fig. 2. Case 1. F. W. Chronic synovitis, possible loose internal semilunar cartilage. Antero-posterior view after oxygen injection. Dark lines above tuberosities of tibia indicate semilunar cartilages. Light area below dark lines indicates oxygen beneath semilunar cartilages.

fore she was permitted to use the limb. There were no ill-effects and she could walk as well as before the injection.

The antero-posterior picture (figure 2) showed a dark line above the external tuberosity of the tibia extending from its external border to the spine. There was a similar line above the internal tibial tuberosity, but it extended only part way across the spine, from the internal border to the junction of the middle and external thirds. These lines were interpreted as indicating the semilunar cartilages, the oxygen having presumably gotten under the cartilages and lifted them up. The break in the line of the internal cartilage was assumed to indicate a rupture of this meniscus. This interpretation was not verified by operation.

CASE II. Mrs. L. had chronic, so-called rheumatoid polyarthritis. Her right knee was moderately swollen, flexed and painful. This joint was in-

jected for purposes of study. The injection was made in the *x*-ray laboratory with the same technic as in the previous case. The knee was painted with iodin, the needle, the glass barrel and the tubing were sterile and I scrubbed my hands as if for an operation and used sterile gloves. The needle was inserted into the knee joint just below and external to the patella. No attempt was made to measure the amount of oxygen used. The oxygen was injected very slowly and when the knee became ballooned up to a degree equal to the enlargement that would be seen in a moderate grade of synovitis, the injection was stopped. *X*-ray pictures were taken and they showed very distinctly the outlines of the joint, the patellar ligament, the cul-de-sac, the bursae, but no discernible abnormalities. During the injection the patient had some discomfort, but it disappeared

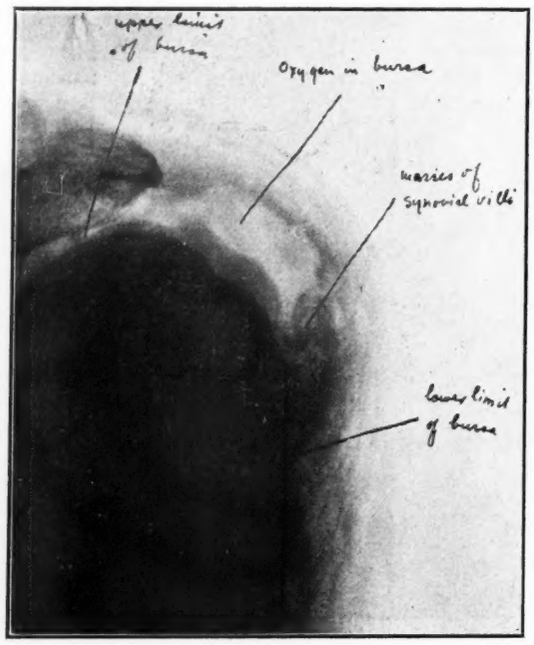

Fig. 3. Case 3. M. R. Subdeltoid bursitis. Antero-posterior view after oxygen injection. Note mass of synovial villi indicated by dark shadow, and oxygen in bursa above this shadow. No communication between bursa and shoulder joint.

when the injection was stopped and was evidently due to the distension of the joint. The gas disappeared within 48 hours and there were no untoward effects. I noticed, however, that the flexion-contraction of the knee was considerably reduced. The patient was distinctly improved after the injection; there was great relief from the discomfort she had been having during her many months of illness. She requested a second injection of the same knee, and later asked that her other joints be injected. This was done. The relief from pain and the reduction of the flexion of the knees were not permanent.

CASE III. Mr. R., 66 years old, had been suffering for a year from chronic subdeltoid bursitis of the right shoulder. There was a very distinct enlargement of the bursa with fluctuation and crepitus on manipulation. The bursa was evidently distended with fluid and a considerable amount of villi. We had learned by this time that no local anesthetic was necessary, for if the needle was inserted rapidly there was only very slight discomfort. The needle was inserted into the bursal sac at a point about one inch below the acromian process on the external aspect of the shoulder. A few cubic centimeters of yellowish turbid fluid were allowed to escape. A tube was then attached to the needle and the oxygen injected. It filled the bursa rapidly, and for the time being caused the patient some discomfort. *X*-ray pictures, then taken, showed the outline and size of the bursa very clearly (figure 3). There was no gas in the shoulder joint proper. The bursa was seen to extend from ⅝ of an inch under the acromian process down over the arm for a distance of 2½ inches. The picture taken with the patient standing up showed gas in the upper third of the bursa and a cloudiness of irregular density in the lower

Fig. 4. Case 4. J. D. Loose body in knee joint. Lateral view after oxygen injection. Note loose body above patella. Pedunculated mass of synovial tissue located above patella and removed.

two-thirds, with a distinct fluid level. The shadow in the lower part was evidently due to the fluid and the villi. These pictures showed not only the outline and extent of the bursa, but also that the bursa in this instance was filled with both fluid and irregular masses of soft tissue. A few minutes after the injeciton the patient had no discomfort whatever. He went home about one hour after the injection and suffered no untoward effects.

The chief points of interest demonstrated by this case are:

1. The practicability of injecting oxygen in an out-patient department, at least in non-weight bearing parts.

2. The subdeltoid bursa can be injected and its outlines demonstrated.

3. The injection of the subdeltoid bursa is neither difficult nor very painful.

4. At least in this case the bursa was apparently not connected with the joint.

CASE IV. Mrs. J. D. complained of a loose body in the knee. She stated that she could feel it and had several times located it at a point just above the patella. On examination the knee was negative. There was no swelling or tenderness, and the loose body could not be felt. An *x*-ray examination was also entirely negative. The knee-joint was then injected with oxygen. The lateral view showed that the joint was thoroughly distended with oxygen and just above the patella there was a shadow about ½ inch square (figure 4). This corresponded with the location where the patient said she had felt the loose body. She was operated upon and a mass of synovial and fibrous tissue was found above the patella,

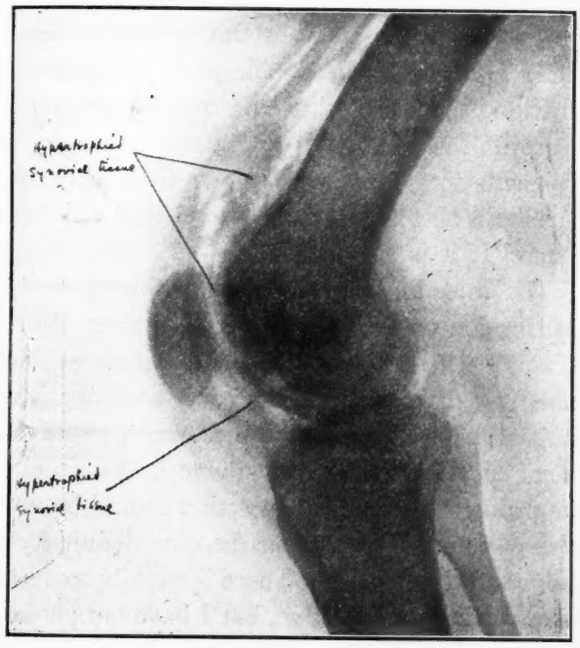

Fig. 5. Case 5. B. B. Tuberculosis of knee. Lateral view after oxygen injection, showing hypertrophy of synovial tissue. At operation, very dense mass of synovial tissue found filling the entire knee-joint. Part of this tissue removed. Microscopical examination showed tuberculosis.

attached to its upper border by a pedicle which allowed a considerable range of motion. This was removed and the patient has had no further trouble. In this instance the oxygen injection was definitely helpful in locating the cause of the symptoms.

CASE V. Miss B. B., 22 years old, was sent to me for a swelling of the lower part of the left thigh and knee. She had had this condition for about two years, but the symptoms had become much aggravated in the last six months. There was great swelling and tenderness in the region of the femoral condyles, and it was feared that she had a neoplasm. *X*-ray pictures were negative. (There was a slight defect in the upper extremity of the tibia, which was not appreciated at this time.) The femoral condyles were apparently normal. The joint was injected with oxygen and again *x*-rayed. The subsequent pictures (figure 5) were entirely different from those taken before the oxygen injection, and were very instructive. They showed a dense shadow of pathological soft tissue filling up the cul-de-sac and apparently joining the quadriceps to the femur. The femur appeared normal and the swelling was, therefore, due to pathological changes in the quadriceps bursa. There was also a shadow of soft tissue in the interval between the tibia and femur. This patient was operated upon and a dense sheet of fibrous and synovial tissue was found lying underneath the quadriceps, joining it to the surrounding tissues. It filled the quadriceps bursa, covered over the femoral condyles and dipped down between the femur and tibia. A large section of this tissue was excised and the wound closed. Microscopical examination showed this tissue to be tuberculous. Subsequently the patient developed typical signs of joint tuber-

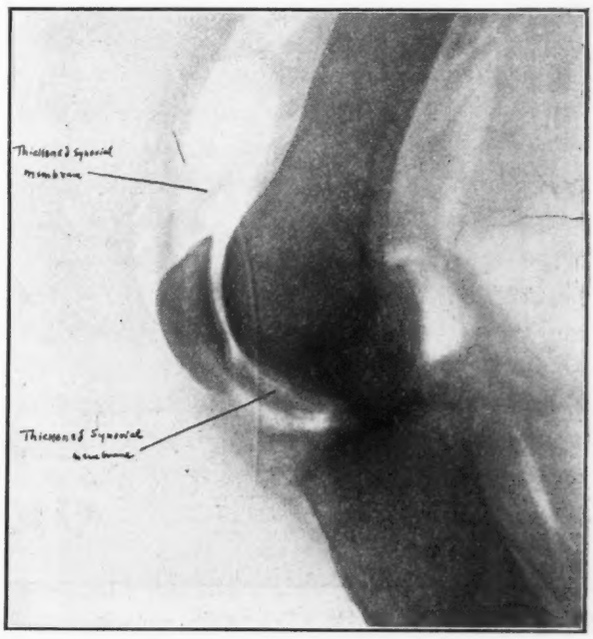

Fig. 6. Case 6. K. A. Traumatic chronic synovitis. Lateral view after oxygen injection. Patient recumbent. Note oxygen (light area) through joint. Also thickened synovial membrane. Note distension of the knee-joint by the oxygen. Very large mass of hypertrophied synovial membrane and villi removed from upper part of knee.

culosis with extensive excavation and loss of tissue of the femur and tibia. In this case the oxygen injection was helpful in definitely locating the pathological changes.

CASE VI. Mr. K. A., 60 years old, injured his left knee two years ago and had as a result a synovitis that resisted all of the usual forms of treatment. The knee was aspirated several times and the fluid was found to be sterile. *X*-ray examination was negative. The joint was injected with oxygen and the pictures (figures 6 and 7) showed an extensive shadow of pathological tissue in both the quadriceps and in the interval between the tibia and femur. The shadow was diagnosed as hypertrophied synovial tissue. At operation the synovial membrane was found to be enormously hypertrophied and congested. A large mass of this tissue was removed and the patient has had no recurrence of symptoms. In this case the injection was helpful in confirming

the diagnosis of hypertrophic synovitis, and justified the advice that an operation was indicated.

CASE VII. Miss T. H., 22 years old, gave a very distinct history of injury to the left internal semilunar cartilage. She had wrenched her knee and since then the joint had become locked several times. There was a mild synovitis and tenderness over the internal semilunar cartilage. *X*-ray pictures were negative. The joint was injected with oxygen and again *x*-rayed. In the region of the internal meniscus there was no abnormality. Above the external tuberosity there was a light line (oxygen) and a darker line above it. The darker line was taken to be the shadow of the external meniscus. This patient was operated upon, the internal meniscus was

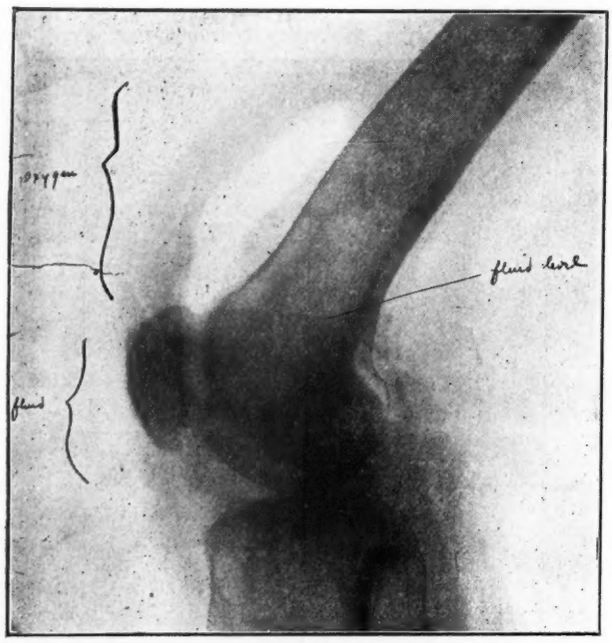

Fig. 7. Case 6. K. A. Traumatic chronic synovitis. Lateral view after oxygen injection. Patient standing. Note upper level of the synovial fluid with oxygen (light area) above it.

found to be very loose and was removed. The external meniscus could not be seen on account of the small size of the incision.

In this case the oxygen injection was not helpful. It was interesting to note the apparent elevation and laxity of attachment of the external meniscus. Sir Robert Jones in a personal interview told me that the external meniscus is normally looser than the internal and that that may explain the appearance in this picture. In other cases injected with oxygen, however, I have not noted this apparent looseness of the external meniscus.

CASE VIII. R. P., male, 10 years old. This patient had what appeared clinically to be a very mild infectious arthritis of the left knee, the cause of which was unknown. *X*-ray pictures were negative. Oxygen was injected for diagnostic purposes. Subsequent *x*-ray pictures were similar to those in case 6; they showed a fairly dense shadow in the quadriceps bursa and in the interval between the tibia, patella and femur. The bones were normal. Evidently there was thickening of the synovial membrane and the boy was suffering from a hypertrophic synovitis. Incidentally it should be mentioned that the joint held very little oxygen. I had the same experience in the injection of other joints of children, namely, that they are very small and hold only a small quantity of gas.

TECHNIC OF THE INJECTION OF OXYGEN INTO JOINTS.

The injection of oxygen into joints is a simple procedure. The apparatus needed consists of a tank of oxygen, a rubber tube about 2 yards long, a barrel of a hypodermatic syringe and a stout needle about 2 inches long. The needle, barrel and tube are sterilized and are attached to the oxygen tank. Some gas is allowed to pass through the tube and needle. This serves the double purpose of clearing the track of the tube and needle, and of gauging the pressure of the gas. It is preferable to use a tank in which the pressure is very low, for if it is high the tube will be blown off the barrel and may break the barrel if it is of glass, and even break the needle. The injection should be made slowly, as sudden distension of the joint is very painful. This is particularly true in the case of children, whose joints are not fully developed and hold only a small amount of gas. I have not found it necessary, or of any value, to measure either the volume of gas injected or the pressure used. The injection should be made very slowly until the joint has become definitely enlarged, and then stopped. There is usually some discomfort during the injection, but I have not yet been obliged to administer any sedatives. It might, however, be advisable to give a small dose of morphine or codein in very nervous patients. The average time of injection is about one to two minutes. The knee, shoulder and finger joints are easy to inject. The elbow I have found difficult to enter and more difficult to inject. I have had no experience in the injection of the hip or ankle joints.

It is much more difficult to inject the joints of children than those of adults, chiefly because of the diminished capacity of the former. Joints that have been distended as a result of synovitis or arthritis are easily injected, and they hold a fairly large quantity of the gas. The oxygen may remain in the joint for several days. In some cases it disappears in as short a time as 18 hours; in others it remains as long as 72 hours. In the average case the gas escapes or is absorbed in 36 hours. I have not tried deflation as practiced in pneumo-peritoneum. Some of the gas, as the pictures show, escapes into

the subcutaneous tissue and intermuscular planes, but it does no harm there. There have been no ill-effects whatever from the use of oxygen in any of our cases. With the exception of the case of subdeltoid bursitis, all patients have been kept in bed until the gas disappeared. This may be an unnecessary procedure, but I had no precedent to guide me and felt that for weight-bearing joints, particularly, complete rest would help to avoid untoward changes.

Up to now the joints have been prepared by thoroughly scrubbing the skin with soap and water just as for a major operation. In knee cases the patient has been kept in bed at least 24 hours before the injection. At the time of injection the skin is painted with iodin. These precautions may prove unnecessary. My experience coincides with that of other observers, that anesthetization of the skin is not required. Having determined the location and direction for the injection, the needle can be thrust into the joint so rapidly that there is no more pain than in an ordinary hypodermatic injection. The needle should be held firmly when in the joint, as moving it may scratch the synovial membrane or bone, both of which are very sensitive. In order to avoid the escape of too much of the oxygen before the pictures are taken, the injection should be made in the *x*-ray laboratory.

CONCLUSIONS.

When I first began my work with the injection of oxygen into joints I was hopeful that this method would enable me to outline loose or injured semilunar carilages. In this I have been unsuccessful, although on one occasion shadows were obtained which appeared logically to outline these structures.

However, in reviewing my experiences, there is no doubt that the injection of oxygen into joints for roentgenography has many advantages and is a great aid in diagnosis. Primarily it accentuates the contrast between the soft parts and bones, and brings into relief soft structures that are not discernible in the ordinary roentgenograms. It is very useful in demonstrating loose bodies in joints, and it is invaluable in locating them. It is helpful also in showing the presence and extent of hypertrophied synovial tissue.

1 WEST 85TH STREET.

Very often the unskilful treatment of a fracture is worse than no treatment at all. Serious deformities may result from the neglect of small details no less than from the violation of important principles.

THE TREATMENT OF JOINT TUBERCULOSIS.

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The treatment of joint tuberculosis shows much difference of opinion, and, as in other diseases in which this condition exists, so here the difference of opinion must rest upon ignorance of fundamentals. Either we all are ignorant, or some of us are ignorant. As long as the treatment of a disease rests purely on clinical experience for its authority, it is bound to be diversified and to change from day to day, for one man's clinical experience is about as good as another's, and his opinion this week is quite different from his opinion next week.

As an example of this, let me quote the case of appendicitis. Before its pathology was known, its treatment was most diversified. With a knowledge of its pathology came a rational treatment, and gradually a standard method of procedure was adopted. Today many men differ somewhat in details of procedure, but no intelligent surgeon attempts to cure the disease with external applications, or by exposing his patient to the sun's rays, or by opening the abdomen and blindly scooping around with a curette. These and many other methods of treating joint tuberculosis will probably disappear when the pathology of the disease is understood. In one part of the country in which I resided for a while the standard treatment was amputation. After I had had a chance to watch for a while the other methods of treatment to which patients were exposed, I was quite willing to concede that in that section of the country the patient who had his limb amputated was about the only one who stood much chance of pulling through!

The pathology of joint tuberculosis as it appears in the text-books is partly mythical and partly a rehash of positive statements made years ago by surgeons of enough reputation to "put them across". Anyone with ordinary intelligence, who is willing to work in a laboratory for a few months can overturn the whole edifice. Let us erect a framework of pathology, and then let us see if we cannot place upon it a habitable edifice of treatment.

Tuberculosis of a joint is the same in its essence as tuberculosis in any other part of the body. It usually starts in the bone, and the peculiarities it enjoys are due to two things: It runs its course locked up in a bony shell; and it usually has in its immediate vicinity a closed cavity, the joint.

Pure joint tuberculosis, that is, tuberculosis not

complicated by the presence of a secondary infection by pus germs, is a disease strictly limited to two tissues, lymphoid marrow and the synovial membrane. The disease may start in either one, and later may involve the other, or it may remain indefinitely in one of them alone. If it remains in the marrow and does not involve the synovial membrane, it is, strictly speaking, not a tuberculous arthritis, but simply a tuberculous osteomyelitis, but in point of fact, if it ever attains sufficient importance to cause clinical symptoms, it almost invariably does involve the joint. It seems to seek the joint as if with a well-defined purpose, and nature's whole protective reaction is in the direction of depriving the joint of function, in other words, of destroying it. This she is very rarely able to do unaided.

Tuberculosis exists in the neighborhood of the joints in the long bones, that is in the ends of the long bones, simply because there the marrow is of the lymphoid variety. Except in young children, the marrow in the shaft consists of little else than fat, and, as is well known, fat is but a poor food or culture medium for the tubercle bacillus. All the world over every living thing domiciles itself where its food supply is best, and all through the body we find that the lymphoid tissues are the great feeding ground of the tubercle bacillus. This is the reason why tuberculosis is found in the spongy ends of the long bones and not in the short and flat bones throughout the body. Simplicity is probably responsible for the failure of recognition of this fact hitherto. It is so much more attractive to speak of rapid or slow blood stream, of congestion following injury (as if the bone or its contained marrow could possibly be injured by anything but a fracture!), of peculiarities in the arrangement of the bloodvessels, or of the "pars minoris resistentiae".

The presence of the lymphoid marrow in the region of the joint seems to depend, at least in the adult, largely upon the presence of function in the joint. The presence of the synovial membrane depends absolutely upon the presence of joint function. When function is destroyed, these two tissues disappear. When they disappear, the disease dies out. It dies out simply because its food supply has ceased. It is starved out. Here we have our first great rule of treatment: DEPRIVE THE JOINT OF FUNCTION.

This rule has two corollaries:

1. *In children,* while the presence of the lymphoid marrow may be somewhat dependent upon function, it is not absolutely so. The disease can exist in the shaft as well as in the end of the bone. Radical operations are not, therefore, invariably successful and, on the contrary, often they entail crippling and unsightly deformities, on account of their interference with the centers of growth. Conservative treatment offers a faint chance of cure and is easily carried out. Therefore the treatment of joint tuberculosis in children is almost invariably conservative. We carry it out until they have at least almost attained their full growth, or until all hope of saving the limb is gone. In the latter case we amputate. Conservative treatment consists first and foremost of immobilization. Other means such as heliotherapy, passive congestion, etc., are auxiliary.

2. *In the adult* the case is entirely different. In spite of all extravagant claims of wonderful cures by various means, the presence of tuberculosis in the region of the joint, of sufficient severity to cause clinical symptoms, means that painless function in that joint is doomed. By conservative treatment, always difficult to carry through in the adult, we may at length succeed in securing a fibrous ankylosis, and in the fibrous adhesions tuberculous foci will be locked up, ready to be set free at any time, even after many years, and start up the whole disease afresh. In other words, the best we can obtain is a stiff and sometimes a painful joint, after years of conservative treatment. We can obtain in a few months a stiff, painless joint, and one in which the disease is permanently cured by radical treatment. Therefore we say, in adults the treatment is almost invariably radical as soon as a positive diagnosis is made. When we operate, we do so, not with any idea of removing much or little tuberculous material, but with the definite purpose of destroying function in the joint, completely and permanently.

When we speak of a positive diagnosis, we mean exactly that and nothing less. No man living can make a positive clinical diagnosis with the aid of the roentgen rays or without it. The demonstration of the tubercle bacillus is the only sure criterion. The demonstration of the bacillus is not practicable in disease of the spine, but fortunately the diagnosis here is more apt to be correct than in the other joints, and we are justified in going ahead on a strong presumption, especially as ankylosing operations entail little interference with the function of the spine as a whole. In other cases the demonstration is quite practicable.

So much for the first great rule.

We have seen that bone and joint tuberculosis is strictly a disease of the lymphoid marrow and of the

synovial membrane. It is in itself a comparatively harmless disease, entailing practically no constitutional disturbance, and with little danger to life unless in the spine it interferes with the functions of the cord. With the advent of a secondary infection the whole picture changes. Tissues previously immune immediately become vulnerable, and instead of a strictly localized, comparatively harmless disease we have to deal with a widespread and a very dangerous one. From this fact we draw our second rule: AVOID SECONDARY INFECTION.

All operations upon tuberculous joints are to be conducted with the strictest asepsis, and when the operation is finished, the wound is to be closed without drainage. The practice of scraping, packing and draining tuberculous joints is responsible for the loss of thousands of lives. Every effort must be expended to prevent the establishment of a communication of the focus in the bone with the outside air. When we attempt to provide by drainage for the exit of tuberculous material we really provide for the entrance of pus germs, and often open the door through which death eventually enters.

The importance of the third rule is generally well understood and needs no emphasis here. In the long run the outcome of the case depends largely upon the resistence of the patient to the disease, and anything that improves his general health makes the prognosis more favorable. Hence the third great rule in the treatment: IMPROVE THE PATIENT'S NUTRITION.

Probably the vogue of sunlight treatment depends in the last analysis upon its favorable influence on the general health. When the patient is exposed to the sun's rays he is also in the fresh air. A few years ago the seashore was being boomed just as enthusiastically as are the mountains of Switzerland today. It always seems necessary to "camoufler" sunshine and fresh air in order to persuade the human race to avail itself of their benefits. The patient should be in the open air as much of the twenty-four hours as possible. A child should remain out of school for at least the early stage of the disease. An uninfected tuberculous joint carries a very small danger to life, but its presence shows ordinarily the presence of a tuberculous focus somewhere else in the body, a focus that may eventually be the cause of death, even after the joint is well.

Conservative treatment consists usually in immobilization, either with some sort of brace or with plaster-of-Paris. Some surgeons prefer one, some the other. Each has its advantages. It is quite useless to apply plaster, or a brace, for that matter, reaching a few inches on each side of the joint. A plaster dressing for the elbow should reach from the axilla to the wrist, one for the knee from the perineum to the malleoli, etc. Bony prominences must of course be padded, but padding is quite unnecessary over muscular bellies, and is out of place there, for with it the dressing can not be made to fit snugly.

When immobilization is begun with a tuberculous joint, one must realize that the treatment must be continued for a year at the very least, almost always for two years, and usually for three or four.

Cold abscesses, if deep seated, not increasing rapidly in size, and not approaching the surface, may be let alone. Otherwise they should be aspirated with a large needle or a trocar, under the strictest asepsis. When they refill they must be aspirated again, but the needle must not be thrust through the same spot in the skin. Some surgeons advise the injection of the cavity of the abscess with some antiseptic, usually a preparation of iodin, but whether or not this is wise it is hard to say. In no circumstances must these tuberculous or cold abscesses be opened and drained. If they are, they will invariably become infected, and will give rise to sinuses that may remain open for years, and eventually be the cause of the patient's death.

In operating upon a tuberculous joint one must remember that the object of the operation is not to remove all the tuberculous tissue. This is quite unnecessary, and more, it is quite impossible. There is no way in which any one can assure himself how far the disease extends in the bone. The operation should be planned with the sole idea of destroying the joint. A small slice is to be removed from the end of each bone of the articulation, the bone ends are brought accurately into apposition, and then are held in close apposition and immobile with plaster-of-Paris or a splint.

In closing the wound it is wise not to approximate too exactly the skin edges, otherwise the inevitable oozing of blood from the bone may give trouble. The plaster dressing may be left on for six weeks or longer. In the absence of infection the wound does not need to be dressed. Because there is no periosteum in the region of the joint, bony union at the seat of the resection is very slow. Usually it takes about a year, but in the knee of the adult the tight fibrous union gives a reliable result after about six months.

Bony union is easy to secure in the knee, but difficult in other joints. In the elbow, bony union does not ordinarily result from a resection. In the wrist,

instead of the customary resection, a graft should be run between the distal end of the radius and the proximal end of the third metacarpal. In the hip, the head of the femur should be removed and the trochanter thrust into the acetabulum. The hip should be put in plaster in moderate abduction for several months. In tuberculosis of the ankle, the talus may be removed, the malleoli freshened, and the foot subluxated somewhat backward (Whitman operation). In tuberculosis of the spine, the best operation is the Hibbs operation, but it is rather difficult, and most operators are content with the Albee operation with the bone graft. It is seen that in neither of these operations does the surgeon work upon the bone in the diseased area, yet cure ordinarily results. Operation is almost invariably the best treatment for tuberculosis of the spine in patients of all ages. Conservative treatment rarely results in cure, and deformity is almost impossible to prevent by conservative treatment.

1. DEPRIVE THE JOINT OF FUNCTION.
2. AVOID SECONDARY INFECTION.
3. IMPROVE THE GENERAL HEALTH.

STANFORD MEDICAL SCHOOL.

BOW-LEGS AND OTHER RACHITIC DEFORMITIES.

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The most common deformities of children resulting from rickets are bow-legs, knock-knees and anteriorly bent tibias. Rachitic deformities usually reach their highest development during the second or third year and the deformities of the bones become firmly established in the eburnizing or hardening stage that follows.

In the early stages of rickets, and before eburnation of the bones, the deformities may be corrected by putting the legs into plaster-of-Paris and holding them in corrected positions with mild manual force until the plaster sets. The child should be encouraged to walk in the plaster for three weeks. Repeat the procedure if necessary. Perfect corrections, especially of bow-legs, can frequently be made by this process.

With eburnation the bones become much denser and harder than when normally ossified and then the deformities can be corrected only by osteoclasis or osteotomy.

Contrary to a quite prevalent opinion that these deformities are produced by too early walking, the most viscious deformities are frequently seen in children that have been so weakened by rickets that they have never walked or even stood alone.

Under favoring conditions of a vitamin-rich anti-rachitic diet, fresh air and cleanliness supplemented by phosphorized cod liver oil, the rachitic symptoms will usually disappear in from one to three months. With the cure of the rickets the bones usually eburnate quite suddenly.

Non-unions after accidental or spontaneous fractures, which are so frequently seen in the fragile bones of acute rickets, are a constant warning against either an osteoclasis or an osteotomy until eburnation is complete.

Fig. 1. (Case I). Boy, aged 5 years, with badly deforming rachitic bow-legs.

The rules for the roentgenographic differential diagnosis of the three stages of rickets that have been given by Robert N. Lovett* should never be neglected. In the acute stage the roentgenogram shows the epiphyses of the tibia clouded and blurred, and the ends of the diaphyses presenting a frayed-out appearance. In the subacute stage the shadows begin to clear. With the eburnation the normal roentgenographic clearness and regularity of outline returns, and not until then should any corrective operation be attempted.

Figure 2 shows a roentgenogram of the out-bent tibias of bow-legs after eburnation. They are more

*Lovett, Robert M. Section on Orthopedic Surgery of the *A. M. A.*, 1915.

dense and hard than normal bones. The ends of the epiphyses are broadened and lipped next to the epiphyseal line, but the lines are clean-cut and clear showing that the bone is ready for osteoclasis or other operative measures.

It is very important that the Gratton osteoclast be rightly used to get the best results. For the correction of bow-legs the procedure is as follows: After anesthetization, the fracturing bar is placed against the outside of the leg on a level with the peak of the deformity and about midway between the retention bars. (See positions in figure 8.) Any interne may turn the screw, with instructions to screw down and to release with the utmost rapidity when so directed. The operator holds the leg in position against the retention bars with both hands. If either retention bar is placed near a joint, the position of the operator's hands will give him a timely warning against any possible slipping into a joint. The fibula always fractures with, or slightly before, the tibia. Immediately after fracturing, the leg should be put into plaster-of-Paris from the perineum to the toes and held in an over- corrected position so that when the plaster sets the legs look like a case of knock-knees. The plaster is usually removed in six weeks, and a week later, after a second photograph is taken, the patient is discharged cured.

For the correction of knock-knees, the fracturing bar must be placed against the inside of the thigh just above the inner condyle. The operator holds the knee with one hand and the thigh with the other against the retention bars, which insures the location of the lower retention bar on the condyle. After fracturing, the leg should be put into plaster-of-Paris from the floating ribs to the toes and in an over-corrected position, so that after the plaster sets it looks like a case of bow-legs.

For the correction of anteriorly bent tibias, the fracturing bar should be placed against the outside of the ankle and close to a level with the peak of the deformity. The fracture of the tibia should be complete and the correction of the deformity by opening up a triangular space in the posterior tibial shaft should be made by manual force and maintained until the plaster has set. This usually lengthens the leg 2.5 cm. To anticipate this lengthening of the leg, a tenotomy of the tendo achillis should be previously made to allow it to lengthen correspondingly. In cases of viscious twisting with 8 to 10 cm. of shortening of the tibias, I have repeated the fracturing and lengthening of the tibias with the accompanying tenotomy of the tendo achillis at different levels, three or four times, at intervals of three or six months. The dwarfed patient was usually as much pleased with a gain of 8 to 10 cm. in height as with the straightening of his crooked legs.

Ample experience shows that three or four lengthenings of the tendo achillis by simple division leaves its strength unimpaired. Experience also shows that the nerves and arteries do not suffer in the least from

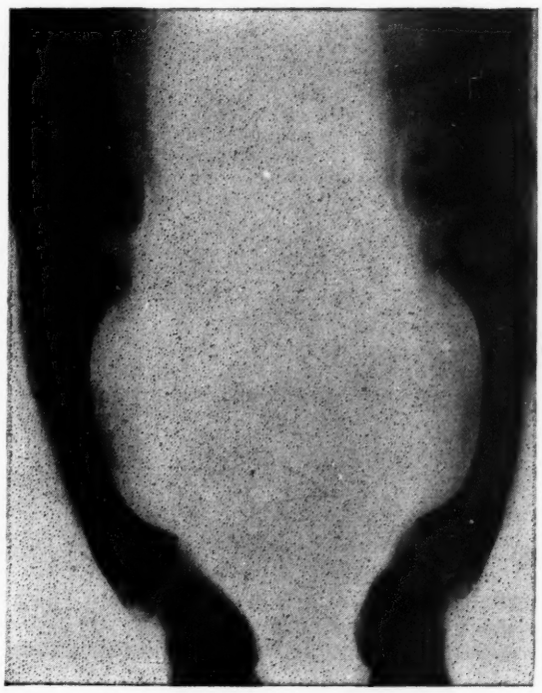

Fig. 2. (Case I). Roentgenogram showing eburnated tibias ready for osteoclasis.

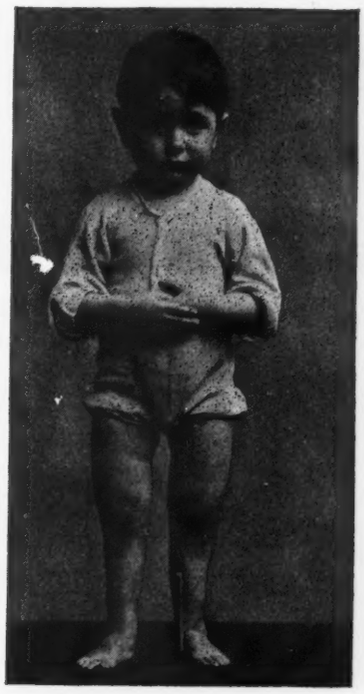

Fig. 3. (Case I). Shows the same boy six weeks after bloodless rapid osteoclasis with useful and symmetric legs.

10 cm. of lengthening if done 2.5 cm. at a time and three to six months apart.

Osteoclasis has many advantages over osteotomy for the correction of rachitic deformities. Better

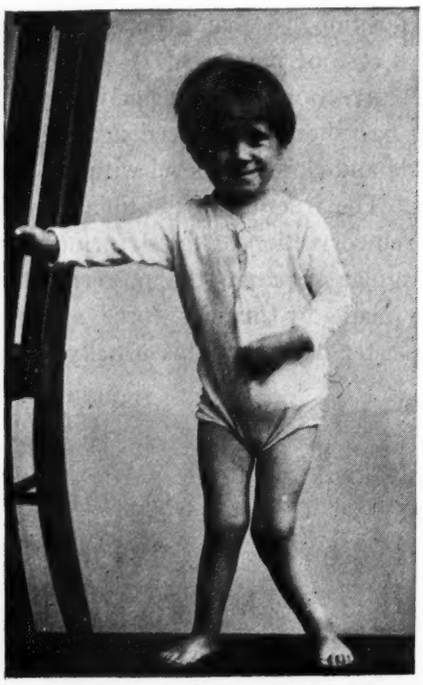

Fig. 4. (Case II). Girl, aged 5 years, with weak and deforming knock-knees, making walking difficult.

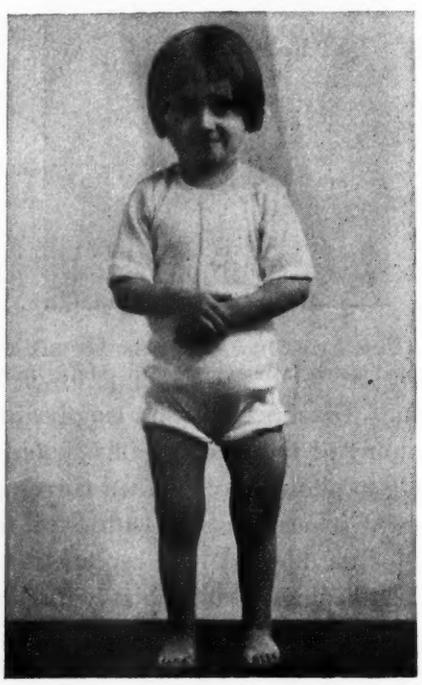

Fig. 5. (Case II). The same girl six weeks after bloodless and rapid supracondyloid osteoclasis with useful and symmetric legs.

symmetry is obtained with osteoclasis. With six to eight seconds for the osteoclasis, eight seconds for the manual correction and eight minutes for applying and setting of the plaster-of-Paris, the patient is on the table only about one-tenth of the time that is required for an osteotomy with its attendant aseptic precautions and dressings.

Rapid osteoclasis is a good term to use, for slow

Fig. 6. (Case III). Girl, aged 5 years, with deforming out- and anterior-bent tibias.

Fig. 7. (Case III). The same girl six weeks after rapid osteoclasis with tenotomy of the tendo Achilles and showing symmetric and useful legs with 2.5 cm. of lengthening.

osteoclasis is dangerous. The Grattan osteoclast is by far the best instrument to use for this purpose.

The best age for osteoclasis is from three to six years. Under three years the bones will usually be

too soft, and over six years too hard, for osteoclasis. In children over six we use osteotomy with the usual antiseptic precautions, but as most of the children presented for correction are of the right age, osteoclasis is used in a great majority of the cases at the Hospital for Destitute Crippled Children, Chicago. This hospital has had a world record for the bloodless correction of rachitic deformities, as can be readily shown by photographic and other records.

Before the late war with Germany, every year Chicago received over seventeen thousand new immigrants from Italy, Greece, Syria and other tropical or semi-tropical countries. None of the children that came in the mother's arms or holding to her skirts developed rickets, but 80 per cent of the first Chicago-born children did develop rickets of the visciously deforming types. The explanation is easy. The poor Italian, Greek and Syrian mother lives at home almost in the open with a diet of fresh fruits, milk and other uncooked foods. When the baby is weaned, it has the same vitamin-filled, antirachitic diet. These mothers live through their first winters of Chicago's snow and ice in squalid backrooms. The families frequently sleep on the floor with a little stove in one corner on which is a kettle containing a ten-cent soup bone and water. This poor excuse for a soup with the addition of a loaf or two of the cheapest bread serves the entire family for several meals a day. The mother gets home at night from a scrubbing job and nurses her baby on starvation milk. When the Chicago-born baby gets to be two or three years old, it is brought to the hospital, a bundle of vicious rachitic deformities. After about seven years the mothers from tropical countries become adapted to their new homes and also reach some degree of prosperity. Then they produce no more rachitic babies.

The children born to Russian, German and Polish Jewish mothers under exactly the same conditions of immigration and living as the Italian, Greek and Syrian people do not develop rickets and rachitic deformities. This fact has caused much speculation, but is easily explained. The northern mothers are acclimated to cold winters and are familiar with diets that prevent scurvy and that equally well prevent rickets.

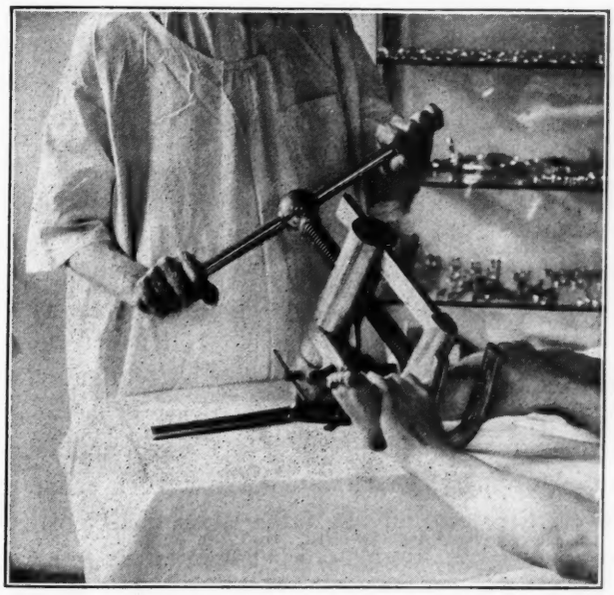

Fig. 8. The Grattan osteoclast in position to fracture the tibia and fibula, with the fracturing bar against the outside of the leg for the correction of bow-legs or anteriorly bent tibias. The retention bars are against the inside of the leg and the operator's hands are grasping the leg close to the retention bars.

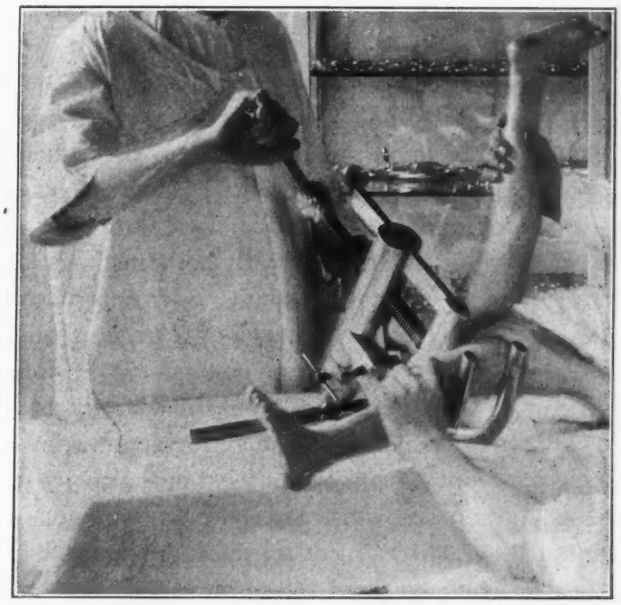

Fig. 9 The Grattan osteoclast in position to fracture the femur with the fracturing bar just above the inner condyle for the correction of knock-knees. The lower retention bar rests close to the lower edge of the outer condyle and its position is guarded by the operator's hand.

Fear has been expressed by operators not familiar with the Grattan osteoclast that when used close to a joint "it may slip over the end of the bone into the joint". I have never seen a joint in the least endangered by the use of the Grattan osteoclast.

In the case shown in figure 6, the deformities will be seen to be very close to the lower ends of the tibias and the osteoclases were done as close to the ankle joints as one could desire to do osteotomies. In the case shown in figure 4, the supracondyloid osteoclases were done quite close to the condyles. In neither of these cases were the condyles in the least danger.

I have never had a non-union following osteoclasis, and the only one that I have known to occur was in

the hands of a careful operator and it antedated Lovett's rule for determining eburnation, or it would not have happened.

Non-unions following osteotomy are of frequent occurrence and are undoubtedly due to the interruption of bone continuity by the chisel and the filling of the open space by extraneous materials.

It is the position in which the legs are placed in plaster-of-Paris after osteoclases that determines both the anatomic and the functional results.

Osteoclasis has proved to be remarkably free from complications. No nerve injury or fat embolism has ever been observed.

15 E. WASHINGTON ST.

THE IMPLANTATION OF TENDONS.

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The transplantation and the fixation of tendons are now firmly established by experience as useful surgical procedures. There persists, however, a great deal of dissatisfaction with both methods of treatment owing to the variability and uncertainty of the results obtained. A review of a large number of patients treated by these methods in various American and British clinics would appear to show that a large proportion of the unfortunate results have arisen from poor discrimination in the choice of patients. Many surgeons, after deciding to give a certain method of treatment a trial, apply it more or less generally to the next thirty or forty cases that present themselves, without much consideration of its applicability or limitations. Thus one frequently sees the tendons of comparatively weak muscles transplanted with the idea of replacing the lost function of muscles whose action must be powerful to be at all useful. An example is seen in the transplantation of the peronei to replace a paralyzed triceps surae. Similarly, one sees tendon fixations performed without a preliminary correction of the skeletal deformity, with the result that the deformity persists after the splints are removed, exactly as it was before the operation, or as it existed on the operating table immediately after the fixation had been performed. It is clear, therefore, that in these as in all other useful operative procedures, much of the dissatisfaction is unjustified owing to the poor judgment of the operators in choosing their patients, or to their lack of appreciation of the principles which must be clearly understood before a method is placed on trial.

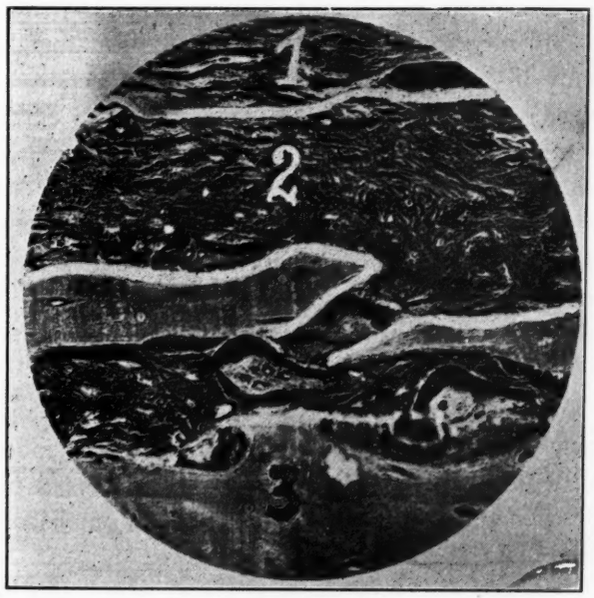
Besides the group of poor results which can be attributed to these errors, however, there remain a considerable number in which the cases appear to have been well chosen and the principles involved in the treatment thoroughly understood. We have observed many tendon transplantations that have appeared to be successful for a time, which have ultimately proven to be failures owing to the separation of the tendon from its new point of insertion. Similarly, in tendon fixations, it is common experience to find that soon after the patient begins to use the limb, the supposedly fixed tendon breaks loose from its point of attachment and the deformity reappears as before. When such results are considered along with those in which the implantation of the tendon has remained permanent, it is clear that the variability of the results must be due to differences in operative technic. It was with a view to determining the essentials in this technic that the following short investigation was undertaken.

Our attention was first directed to the subject shortly after the publication of our first papers on "Tendon Fixation" in 1913.* Several patients reappeared in the clinic several months after the operation, with a complete recurrence of the deformity. These included a case of varus in which a fixation of the peronei had been performed, a case of calcaneus in which the tendo achillis had been fixed, and a case of valgus in which an attempt had been made to correct the deformity by fixing the tibialis posticus tendon. When the plaster bandages were removed two months after the operations, the feet were in excellent position, and the adhesion of tendon to bone seemed firm. Yet with a month or more of ordinary walking the tendons appeared to be as movable as before operation. These patients were immediately subjected to a second operation and it was found that in each case, although the tendon lay in a groove in the bone, this groove was lined with areolar tissue that closely resembled the ordinary areolar sheath of normal tendon. Any adhesions that did exist between the tendon and the bone were long and slender and offered no resistance to recurrence of the deformity. The original technic employed consisted of roughly exposing the tendon and burying it in a groove cut in the bone, and, after drawing it taut, fastening it in place with absorbable sutures. This technic was now changed and attention was directed towards the complete removal from the tendon of all areolar tissue, and the result was a

*_Annals of Surgery_, March 1913. _Journal of the American Orthopedic Association_, July, 1913.

marked improvement in the percentage of successes obtained.

There remained, however, a small proportion of cases in which the tendons seemed to pull loose, and second operations performed on these patients showed that the failures had resulted from stretching of the scar tissue that united the tendon to the bone. In some instances large areas of the buried tendon were glistening as at the time of the original operation and the adhesions were scanty and very weak. Before we had reached this stage in our observations we had begun to employ the operation of



High power photomicrograph of a longitudinal section of a tendon which had been fixed in a trough in the bone one year previously. The borders of the various structures are indicated diagrammatically by white lines drawn on the photograph. 1. Longitudinal section of tendon. 2. Fibrous tissue uniting tendon to bone. Note the irregular arrangement of the fibers as compared with the parallel arrangement in the tendon. 3. Bone.

tendon fixation in patients in whom the muscles were only partially paralyzed, but in whom deformity had developed. In these cases only half of the affected tendon was buried in the bone and the remaining half left to carry out its ordinary function.* In no case so treated have we ever observed a recurrence of the deformity. This observation suggested that more certain union might be obtained by placing the cut surface of the tendon in contact with the bone instead of the superficial surface. The technic was accordingly modified and the tendons thoroughly scarified and split longitudinally before being laid in the groove. More recently, the probability of solid union has been increased by forcing some of the chips of bone removed in cutting the groove among the strands of the split tendons, before closing the periosteum over them. Since this technic has been employed we have seen no cases of failure to obtain solid union of the tendon to the bone.

Some surgeons have supposed that more certain union can be obtained by cutting the tendon free from the muscle and threading it through a hole in the bone. Our investigations have shown that this is a mistake, however, as recurrences of deformity develop quite as frequently after this technic as after that described. This is but natural as the principle involved is the same in each case. If it is preferred to thread the tendon through a hole the same precautions must be observed in removing the areolar sheath and in placing raw surface of the tendon in contact with the bone, otherwise a high percentage of failures will result.

The histological changes produced by such operations have been carefully observed both in humans and in animals. Tendons are composed of parallel white fibers arranged in bundles which are separated by a minute amount of areolar tissue which carries the bloodvessels and lymphatics. These septa of areolar tissue pass into the tendon from a delicate sheath which covers its surface. Between the parallel fibers lie the tendon cells. When a tendon is injured, as in a simple tenotomy or in splitting it longitudinally, it undergoes the ordinary inflammatory reaction associated with repair. The bloodvessels in and about the injured part become engorged and an exudate occurs which produces the usual edema and infiltration with inflammatory cells. Cellular proliferation goes on in the line of the wound, and ultimately healing occurs by the production of an ordinary scar. In the process of repair, however, the tendon cells and the fibers appear to take no active part, as the edges of the wound remain clean-cut throughout, and no proliferation can be seen in the tendon cells themselves. The cellular proliferation appears to arise from the areolar tissue on the surfaces and among the bundles of fibers. Moreover, the scar that is ultimately produced does not resemble normal tendon at any stage up to six months after operation, which was as long as we continued to recover specimens. The fibers are thinner, more loosely arranged, and do not assume the parallel arrangement to which tendon owes its great strength. It is evident, therefore, that wounds of tendons heal by means of a tissue which is really ordinary scar tissue and which has the defects of such tissue in that it will readily stretch when subjected to strain. This has been clearly

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demonstrated clinically in the operation of transverse subcutaneous tenotomy. This operation has been practically abandoned, owing to the stretching which so frequently occurs in the scar that unites the cut ends of the tendon.

When it is realized that the healing of tendon to bone or of tendon to tendon depends on ordinary scar tissue, it is clear that if the union is to be strong enough to withstand high degrees of strain, it is not only essential that we shall make certain of the formation of tough scar tissue by placing raw surfaces together, but also that we shall place these surfaces together over considerable distances. This principle has been adopted in the various tendon-splitting operations employed in the lengthening of tendons, but its importance has not been appreciated in tendon fixations and transplantations or in the ordinary suture of severed tendons. While a simple end-to-end suture may sometimes be quite sufficient in a wound of such a tendon as the extensor indicis, where the strain will be very slight, it will prove quite inadequate in wounds of the flexors of the hand and wrist or the powerful flexors of the foot. Similarly, many failures in tendon fixation and transplantation can be attributed to the smallness of the area of contact of the raw surface. When it is intended to unite tendon to bone or tendon to tendon, the surgeon must keep in mind the degree of strain to which the points of union will be subjected, and prepare the part to be sutured accordingly. For example, in fixation of the peronei it is sufficient to bury the split and scarified tendon in a tunnel about two inches long, but if it is intended to fix the tendo achillis, it must be buried for three or four inches. Similarly, in the transplantation of tendons, the distal end of the tendon, after being split and scarified, must be threaded through a hole in the bone sufficiently long to ensure abundant scar formation. Nothing is more futile than the suturing of the end of a tendon to the periosteum or the fastening of it into a small groove in the bone. As soon as strain is applied the tendon pulls out and the whole operation fails. The same rule applies in the suture of tendon to tendon.

Great advance has been made in recent years in the treatment of limbs that have sustained irreparable injuries to nerves. Nothing could be more brilliant than the results that have been obtained from transplantation of flexor tendons of the forearm to assume the function of the extensors that have been paralyzed by gunshot wounds of the musculo-spiral nerve. But many of the operations have been failures, or only partial successes, owing to stretching of the scar at the point of union of the tendons. To reduce the element of chance in these operations, some surgeons have advocated the use of silk or linen sutures. Such materials, however, have the well known disadvantage that they are apt to produce irritation, even weeks after the operation, sufficient to necessitate their removal. Moreover, there is no reason to believe that a non-absorbable suture will assist materially in the permanent union of such structures, for there are abundant examples of their cutting out under ordinary degrees of strain. At any rate, their use is quite unnecessary, as there is no difficulty in inducing tendons to heal together firmly if raw surfaces are placed in contact over a sufficient distance. A most convenient and certain method of doing this is to splice or braid one tendon into the other as in splicing a rope. If this is done over half an inch in a small tendon as the extensor longus pollicis, or over an inch or more in a larger tendon such as the extensor carpi radialis, and ordinary absorbable sutures are employed, solid union can be confidently anticipated.

The views herein expressed have been developed from observation of many operations on tendons and from a series of experiments on animals, a partial report of which has already been published.* They may be summarized as follows:

1. Wounds of tendons heal by ordinary scar tissue which is produced by the areolar membranes on the surfaces and the connective tissue trabeculae which separate the bundles of fibers.

2. This scar tissue, when subjected to strain, is liable to stretch or break unless it is present in considerable quantities.

3. To unite tendon to bone as in tendon fixations or transplantations, it is necessary to place it in close contact with the bone over a considerable distance in order that the scar tissue may be strong enough to withstand the anticipated strain. It is also necessary to remove all the areolar membranes from the surface and it is preferable to split the tendon in order that the raw surface may come in contact with bone.

4. To unite tendon to tendon it is necessary to place raw surfaces in contact over sufficient distance to ensure the required strength in the scar. This may be conveniently done by braiding or splicing one tendon into the other.

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THE FREE TRANSPLANTATION OF TENDONS.

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The surgery of the free transplantation of tissues has made rapid strides within the past twenty years. During this time free transplantation of bone has passed out of the experimental stage and has become one of the recognized surgical procedures, almost as safe as a gastro-enterostomy. The technic of the free transplantation of tendons has not yet reached this stage of development, but it, too, has made a big advance. The very fact that there is still much to be done before it can be considered a finished surgical procedure renders the subject one of double interest to all who are engaged in reconstruction surgery. When one considers that scarcely eight years ago Wilhelm Müller of Rostock could only express the hope, till then unbased on fact, that future surgery might be able to replace the loss of tendons by free transplant, and that within these eight years a method has been found that renders this operation feasible in a high percentage of cases, the progress of this particular phase of surgery is evident.

Lexer has unquestionably done more abroad than anyone to further this development. In our own country I should place first the name of Sterling Bunnell, of San Francisco, whose work in this particular field is all too little known to the medical profession. In 1918, in a short article in *Surgery, Gynecology and Obstetrics,* he published a report of some of his operations and described a technic which in its simplicity and ingenuity at once impressed me as being superior to that used in any clinic either here or abroad. The essential in the Bunnell method is the principle of non-traumatism; the tendon must be regarded as an exceedingly friable tissue and every attempt must be made to retain intact the gliding cells whose importance had already been emphasized by Biesalski and Mayer. To facilitate the suture of the transplanted tendon, Bunnell devised a special clamp, so constructed as to hold the tendon fibrils firmly together during the application of the suture, instead of disrupting them as usually occurs when the tendon is grasped with the forceps. By the use of this clamp and by other refinements in the technic, Bunnell was able to report a number of instances in which total loss of the flexor tendons of the fingers had been successfully replaced, even to the extent of restoring almost the full motion of the injured phalanges.

Until the appearance of Bunnell's article, my own experience with tendons had been confined almost entirely to the pedunculated transplant, or what might be better termed the transfer of tendons. In the pedunculated transplant the tendon is left attached to the muscle and the operation consists merely in changing its point of attachment. Thus in utilizing the peroneus longus tendon to replace the paralyzed tibialis anticus tendon, the peroneus longus is divided where it grooves the cuboid bone and, after lifting it from its bed, it is simply shifted from the outer side of the foot over to the inner and attached to the internal cuneiform. In this procedure, if the operator has a knowledge of the blood-vessels of the tendons, the main nutrient artery can almost always be preserved intact and the vitality of the transferred tendon is thus assured.

In the free transference of tendons the problem is rendered much more difficult, since the blood supply must be entirely destroyed and the vitality of the transplant is thus dependent on the accuracy of the coaptation of tendon to tendon and upon the delicacy with which the transfer is made. Whether the tendon lives in part or whether part of it necroses is a question which still awaits positive answer. Gallie and LeMesurier in a recent paper before the Orthopedic Congress in Boston, June 4, 1921, reported that in their researches the nuclei of the transplanted tendons invariably retain their staining properties and gave every evidence of escaping necrosis. Other observers (Neuhof) incline to the view that all transplanted tissue dies and is replaced by the activity of the surrounding tissues. Whatever the actual fate of the tendon cells may be, certain it is that clinically a tendon can be transplanted and that it can function without any evidence of losing its vitality.

The laws that have already been enunciated for the successful performance of a tendon transfer (pedunculated transplant) apply with even greater force to the free transplantation. The primary consideration is a knowledge of the anatomy and physiology of tendons and an attempt to reconstruct, so far as possible, the normal gliding mechanism (see Mayer, Physiological Method of Tendon Transplantation, *Surgery, Gynecology and Obstetrics,* February, March, April, 1916). In brief, the tendons are normally equipped with a distinctive gliding mechanism. Where the tendon is running a straight course, this consists of an investiture of loose areolar tissue peculiarly rich in elastic fibers, to which I have applied the term "paratenon". This

tissue, lying between the tendon and the fascia, permits a free gliding motion of the tendon. Where the tendon changes its direction, this tissue would not suffice to prevent friction, since the tendon would impinge against bone or restraining ligaments. It is therefore at this point that a sheath surrounds the tendon. The sheath is a sack filled with fluid and acts as a buffer to diminish the friction. At the upper pole of the tendon a valve-like structure is invariably present which closes off the tendon sheath and at the same time permits the free to-and-fro motion of the tendon. This structure is called the "plica". The surface of the tendon is coated with cells which morphologically and functionally differ from the cells of the deeper strata. These superficial cells, frequently resembling cartilage cells in their morphology, seem intimately concerned with the gliding function, since their removal invariably causes adhesion. Injury to them must therefore be avoided wherever the gliding function should be maintained; they must, on the other hand, always be removed when the operator desires to cause fixation of the tendon either to the bone or to some other tendon to which it is to be spliced.

An adequate conception of the method and application of free tendon transplantation can best be gained by the description of a number of typical cases.

CASE I. Jean K., aged 4, while walking through a hay field was run down by a mowing machine which almost amputated both legs. The left was cut across about 3 inches below the knee, the right about 1 inch above the ankle. All the bones and the anterior soft structures were completely divided and the legs were left hanging by the posterior muscles only. Despite severe hemorrhage the child's legs were saved. When first seen by me four months after the accident the bones, though still ununited, showed signs of callous formation. There were several discharging sinuses leading down to small sequestra. Both feet were in a position of extreme equinus owing to the division of all the anterior muscles. The child was unable to walk. After several preliminary bone operations to remove sequestra and secure an aseptic field, the following free tendon transplantation was performed on the right foot.

Through a curving incision on the dorsum of the foot with its convexity towards the toes, the distal portion of the tendons of the tibialis anticus, extensor proprius hallucis and extensor longus digitorum were exposed. The skin flap was retracted upward and the tendons dissected upward until the severed ends were found bound by scar tissue 1 inch below the ankle joint. Through a corresponding curved incision 2 inches above the ankle joint with its convexity towards the knee, the muscle bellies of the three injured muscles were exposed and traced downward until their tendon ends, which had been severed by the mowing machine, were dissected free. In each instance a slight amount of tendon was still found attached to the muscle fibers. The tendon ends were freshened so that healthy tendon fibrils were exposed. Between the proximal and distal tendon stumps was a gap of about 2½ inches. Using No. 1 chromicized catgut, the Bunnell stitch (see figure 1) was inserted into the proximal and distal stumps. As the extensor proprius hallusis was found extremely small, it was united to the extensor longus digitorum by means of this stitch. The next step consisted in boring two channels through the scar tissue at the ankle joint as nearly as possible in the location of the normal tendon sheaths. These channels were made by means of an appropriately

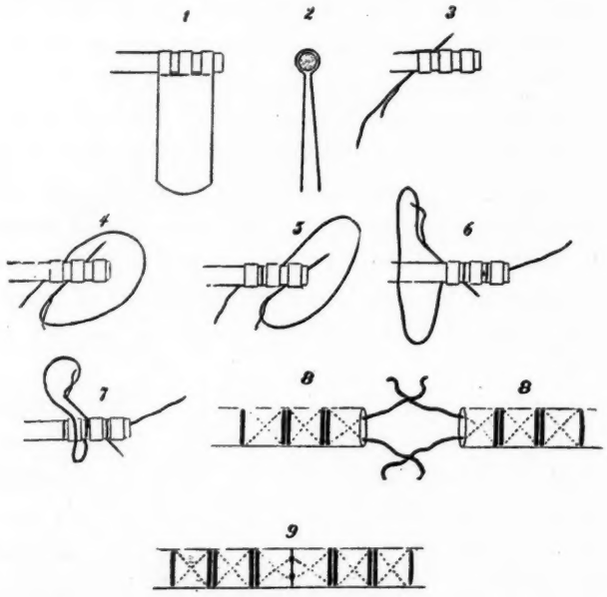


Fig. 1. Diagram illustrating the insertion of the Bunnell stitch. 1. The clamp applied, viewed from the side. 2. View of the free end of the tendon with the clamp applied. 3. Starting the stitch with the first needle. 4. Second stitch with the first needle. 5. Third stitch with the first needle. The needle emerges at the cut edge of the tendon. 6. Starting the first stitch with the second needle. 7. Second stitch with the second needle. 8. The stitches have been inserted into both tendon ends preparatory to knotting them. 9. The sutures have been knotted and the ends cut off short, bringing the tendons into accurate apposition.

shaped clamp and were sufficiently wide to permit the free passage of a tendon the size of the normal. The peroneus longus tendon was considered most suitable for transplantation purposes, since it alone would afford adequeate length for the entire operation. It was exposed through a 6-inch incision running along the outer portion of the calf downward towards the cuboid bone. The tendon was cut just above the cuboid and the Bunnell stitch inserted into the lower end. Three inches of tendon were then measured off and at this point the tendon was again divided, lifted gently out of its bed, and by means of the chromic suture already inserted, it was drawn without any trauma downward through the channel already prepared for it, and its lower

end united to the distal tibialis anticus stump. To measure off accurately the correct length of tendon required, the foot was flexed to a right angle and the upper end of the tendon graft cut away until it exactly approximated the proximal tibialis anticus stump. This involved removing about half an inch. The Bunnell stitch was again inserted and united to the proximal tendon. In this way the reconstruction of the tibialis anticus tendon was accomplished. An exactly similar procedure was carried out for the two extensor muscles. The operation was completed by fine catgut continuous skin sutures. The leg was immobilized in plaster in the position of maximum dorsal flexion.

Immobilization was maintained for three weeks,

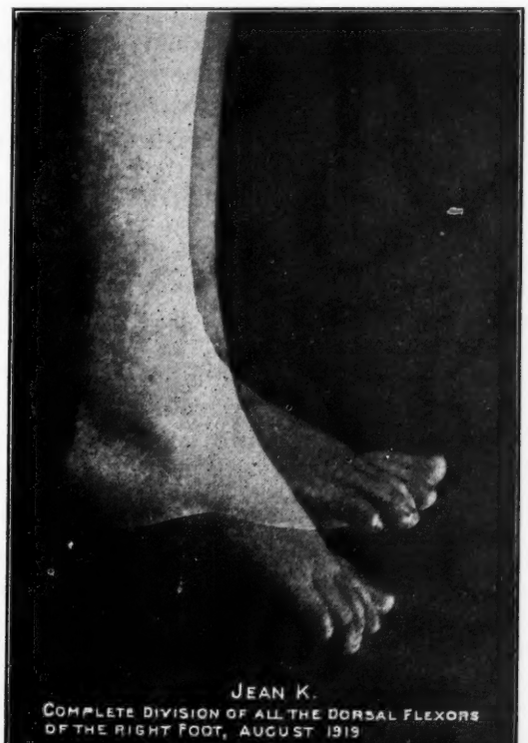

JEAN K.
COMPLETE DIVISION OF ALL THE DORSAL FLEXORS OF THE RIGHT FOOT, AUGUST 1919
OPERATION, FEB. 1920
PHOTOGRAPHED, NOV. 1920

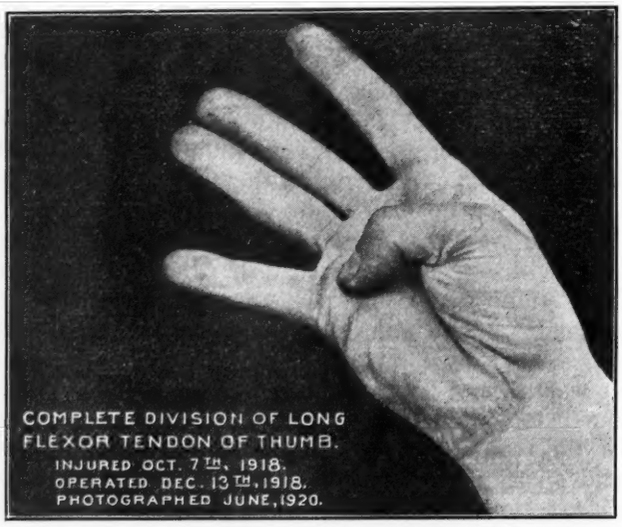
Fig. 2. Photograph illustrating the range of active motion eight months after the free transplantation of portions of the peroneus longus tendon to bridge a 3-inch gap between the divided dorsal tendons. The strength of the tendons is very nearly equivalent to the normal and the patient is able to walk without a limp.

then the plaster was cut down to form a bivalve splint and active exercises begun. Within a week the child was able to move the leg a trifle, and within a month there was 10° of active motion at the ankle. This has gradually increased until at the present time there is almost the normal range of motion (see figure 2). The leg is as strong as the normal and the child is able to walk without a limp. The transplanted tendons can be distinctly felt gliding to and fro at each muscular contraction.

CASE II. Mr. H., a druggist's clerk, severed the long flexor tendon of the right thumb near the base of the proximal phalanx. Owing to the "flu" epidemic and to deaths in his family, he was unable to give the finger suitable surgical attention, and when seen by me two months after the accident, there was complete inability to flex the distal phalanx. The function of the hand was decidedly diminished. Examination of the muscles showed that the palmaris longus which would have been the tendon of choice for transplantation purpose, was absent. It was therefore decided to use a portion of the flexor carpi radialis in case a graft proved necessary. At the operation, which was performed under general anesthesia with an Esmarch bandage applied just below the elbow, the first incision was made over the lateral aspect of the distal interphalangeal joint and curved slightly near the tip so as to permit the retraction of a suitable flap. The distal stump of the flexor longus pollicis was found just proximal to the joint, only slightly adherent to the surrounding tissues. The tendon end was slightly fusiform and covered with glistening tissue resembling the normal gliding surface of the tendon. The end was freshened and the Bunnell stitch was inserted using No. 1 Pagenstecher linen. The proximal stump of the flexor longus pollicis was found through a 2-inch incision running downward from the annular ligament in the course of the tendon. It was seen to be much more densely adherent than the distal stump, but despite the adhesions, the course of the tendon sheath could be distinctly recognized and, instead of boring a passage, it was possible to pass a probe downward through the empty sheath and dilate it to the normal size by means of a curved dressing forceps. Between the tendon ends was a gap of 2½ inches. The proximal stump was threaded with Pagenstecher linen in the same way as the distal had been. The third incision exposed the flexor carpi radialis tendon above the annular ligament. It was found to be distinctly larger than the injured flexor longus pollicis. Accordingly the entire tendon was not used but two-thirds of it was split off longitudinally, the line of cleavage following one of the natural divisions of the tendon. The paratenon which normally covers this tendon was left intact. One end of the tendon was threaded with the Bunnell stitch and drawn downward through the tendon sheath and united to the distal stump, the upper end of the tendon was then accurately measured off to abutt against the proximal stump and united to it. The thumb was immobilized in complete flexion so as to take all strain off of the suture line. Active and passive motion were begun on the fourteenth day. About a week later the distal wound opened and one of the Pagenstecher sutures was extruded. Despite this, the motion of the transplanted tendon did not seem to be interfered with. Within two months the patient had almost the normal range of motion and within a year full function of the finger and hand had returned (see figure 3).

CASE III. Minnie C., a machine operator, sustained an extensive injury to the right hand which resulted eventually in necrosis of the extensor tendon of the fourth finger. The finger was held in the flexed position and could not be used at all. Amputation had already been advised. Even the action

of the lumbricals and interossei had been entirely destroyed by the infection. It was evident even before the operation that the entire common extensor tendon from the metacarpo-phalangeal joint downward almost to the distal interphalangeal joint was absent. The operation was conducted under general anesthesia with an Esmarch bandage applied just below the elbow. A 3-inch incision was made along the radial aspect of the fourth finger. As had been expected, the tendon was found entirely absent for a distance of two inches, that is, from the base



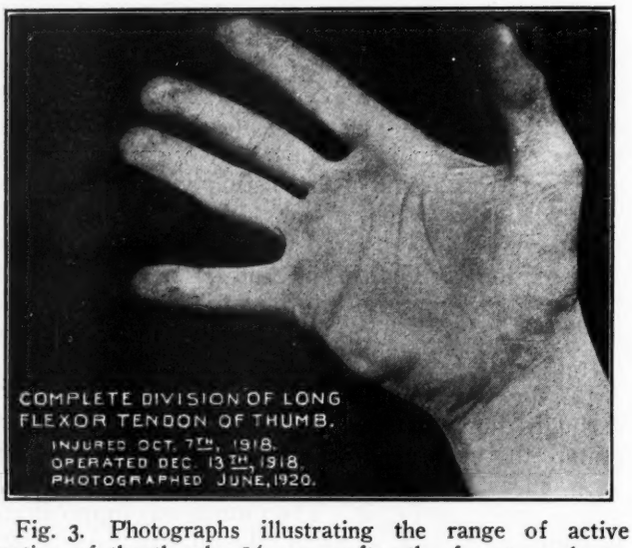


Fig. 3. Photographs illustrating the range of active motion of the thumb 1½ years after the free transplantation of a portion of the flexor carpi radialis tendon to bridge a 2½-inch gap between the ends of the divided flexor longus pollicis tendon. The patient is a druggist's clerk and is able to perform the most delicate manipulations with the injured hand.

of the proximal phalanx to the middle of the distal phalanx. The surface of the bone was roughened and it was evident that if a tendon were tranplanted it would, within a very short time, become adherent to the roughened bone. It was therefore decided to construct a sheath for the transplanted tendon. A strip of fascia from the right calf 2 inches long by 1½ inches wide was removed and implanted over the roughened bone with its gliding surface turned towards the skin. The tendon ends were left free, lying against the gliding surface of the fascia. A 2-inch incision was then made over the extensor tendons of the index finger. The more superficial of these, namely, the branch from the extensor communis digitorum, was threaded with the Bunnell stitch and attached to the proximal and distal tendon stumps which had previously been prepared by insertion of the corresponding sutures. The ends of the fascia were then drawn about the implanted tendon and sutured in such a way as to form a tube through which the newly constructed tendon could glide. A splint was applied holding the finger extended. Motion was begun on the fourteenth day. Owing probably to the complicated operation and to the unfavorable condition of the bone, the result of this case was not as perfect as in the first two, but enough gliding of the transplanted tendon occurred to demonstrate the feasibility of the method and to encourage me in the hope of greater success in the next case.

CASE IV. Mrs. G. This patient had a severe infection of the fourth finger of the left hand. The tendon sheath became involved and, despite vigorous surgical measures on the part of a competent surgeon, the tendon itself became necrotic and sloughed away. When first seen by me about three months after the onset of the infection, there was still a superficial granulating wound on the base of the fourth finger. The finger was held acutely flexed and prevented the patient from using the hand. The possibility of a tendon transplant was suggested by the family physician at this time, but I had little hope of its feasibility, so extreme was the scar tissue formation. The finger was gradually stretched by means of celluloid splints each bent in such a way as to take advantage of the slight improvement gained by the preceding. Within two months the contracture had been entirely overcome and the range of passive motion much improved. No active motion was possible. All treatment was then suspended for a time and the patient allowed to use her hand as she wished, except that a little celluloid splint was applied at night to prevent the contracture from returning. Eight months after the original infection the scar tissue had loosened sufficiently to warrant an attempt at tendon transplantation. General anesthesia was used and an Esmarch bandage was applied just below the elbow. A lateral incision was first made over the distal interphalangeal joint, the flexor profundus tendon identified and threaded with the Bunnell stitch, using No. 1 chromicized catgut. A second incision was made at the base of the finger and the proximal stumps of the flexor sublimus and flexor profundus were found fused together and imbedded in scar tissue. They were left attached to one another but freed from the surrounding tissue and dissected upward for a distance of 1 inch. The free end was trimmed away until healthy tendon became visible. A channel was bored from the base of the finger to its tip running through the scar tissue in the line of the original sheath. Through this sheath a corresponding length of palmaris longus tendon, still covered with para-

tenon, was drawn and fastened to the injured tendons by means of the Bunnell stitch. Continuous skin sutures. The finger was immobilized in a flexed position. Active and passive motion were begun on the fourteenth day. At the present time, six weeks after the operation, there is almost the normal range of active motion at the metacarpophalangeal joint, 25° of motion at the proximal interphalangeal joint, but practically no motion at the distal. The lack of motion at the distal joint is probably due to the marked destruction of the joint itself, rather than to lack of function of the tendon. The patient uses the finger for almost all purposes and considers her hand almost normal.

These four cases, taken from a series of twelve, indicate different types of injury for which the free tendon transplantation may be used. They are characteristic of a group in which the tendon transplant is used for the purpose of reconstructing a tendon and thus utilizing the normal function of a muscle which would otherwise be quite useless. I am not dealing in this paper with the use of tendons as ligaments for the strengthening of weak joints or, as has been suggested by Gallie, for approximation of bone fragments after fracture of the patella or of the olecranon process. It is self evident, that, if a tendon will heal in and can be made to glide, the much simpler operation of implanting it, with the idea of fixing it to the surrounding tissues, will almost invariably succeed. The surgery of tendons is most decidedly in the process of growth and much still remains to be said about the best method of free transplantation. This paper is written not to dogmatize, but to indicate a line of procedure which appeals to me because it seems physiological and because it has given gratifying results in 75 per cent of the cases.

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CLINICAL AND THERAPEUTICAL REMARKS ON CONTRACTURES FOLLOWING WAR WOUNDS.

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From the earliest months of the war, contractures following injuries of the limbs showed themselves in unexpected numbers. These have been divided into two groups: Some, not entirely resistant to passive traction, reducible under the influence of an Esmarch bandage, or anesthesia, are true contractures of psychic or reflex origin. The others, entirely irreducible, by whatever method, are pseudo-contractures, due to fibrous adhesions, musculo-tendinous retractions, muscular fibrosis, musculo-cutaneous adhesions, etc. In practice this division has not appeared so simple, but, in common with Dr. Roger, I believe that up to a certain point we can differentiate certain types, causes and methods of treatment.

Some contractures can be said to be functional and with no organic lesion left by the injury to account for them. They are psychological or even simulated. They do not always take on any particular form, but simulated contractions more often assume an imitation of "fixation" than of "creation", and contractures are often but a persistence, without any reason, of a recognized pathological symptom of organic origin, all wounds involving a muscle being associated with a certain degree of contracture.

However, if certain purely functional contractures can simulate perfectly contractures of organic origin, there are others that, by their aspect, reveal their etiologic diagnosis. We mean certain bizarre conditions, such as crossed fingers, etc., in which their very peculiarity is indicative of a neurosis (figure 1), and also a rather large group of contractures *in extension*. Leaving aside talipes equinus and equino-varus, we can say that nearly all contractures of organic origin are *in flexion;* functional contractures are often also in flexion, but when we see a contracture in extension, it is in all prabability functional. In this group we have two common types, those of the leg and those of the hand.

Quite frequently the patients, wounded or not, come to us with the leg extended and stretched. It is one of the easiest attitudes to adopt and to hold;

all attempts at forcible flexion fail. The quadriceps muscle is powerful and resistant. In every case with or without a more or less slight wound of the anterior aspect of the thigh we have been able to convince ourselves on the field that we were dealing with a contracture, not only functional but even simulated, and we have reduced it at once by force and by treatment "moral" rather than truly psychotherapeutic. We have never observed, following peripheral wounds, contractures in extension of the leg of organic origin. If such a contracture exists, it certainly is very rare. A common functional va-

Fig. 1. Neuropathic contraction of the hand. The peculiarity of the attitude shows immediately the functional origin. Cured in one sitting by suggestion.

Fig. 2. Contraction in flexion of the hand and fingers, following traumatism (explosion of shell).

riety is contracture in extension of the hand and finger. Several varieties manifest themselves. Sometimes the fingers are stretched and spread, either all the fingers or in groups of two or three. In these cases malingering seems to be a game. In other cases we find the hand stretched out but the fingers close to each other, sometimes overlapping in the classical attitude of the "obstetrical hand" (figure 3). This attitude, due to the contraction of the interossei, appears to be essentially functional, more often neuropathic than simulated. Babinski and Froment consider this "obstetrical hand" to be "reflex" or "physiopathic".

Among the organic contractures following war wounds we have classified three groups, without pretending that these are the only ones that deserve to be recognized.

1. In a great number of cases the projectile passed at *the level of, or in close proximity to, the contracted muscles.* These are the cases, for instance, with the biceps in the arm or the posterior muscles of the thigh in contractures, in flexion of the arm or leg (figure 4). These contractures are sometimes so pronounced that the segments of the limbs are at right angles to each other. These contractures are considered by some to be psychopathic or pseudo-contractures due to musculo-tendinous contractures, or to muscular fibrosis. Applying the Esmarch bandage at the beginning of the extremity will relax the contractures, but not the pseudo-contractures, and it determines the diagnosis in each case. In

Fig. 3. Obstetrical hand, of functional origin.

reality the Esmarch bandage does not relax them entirely, but, as we shall presently show, this does not prove that we are dealing with a true contracture.

However, whatever the cause, the etiology has very often been revealed to us by the *x*-ray (figures 4, 5, 6, and 7). In a large number of cases we have found either fragments of metallic substances, more or less voluminous, or what was more frequent, a disseminated metallic dust. This dust, sometimes not revealed by the *x*-ray, is evidently the source of irritation, not so much on the motor nerves as in the muscle fibers themselves.

Certainly we are not dealing here with psychopathic contractures, and less still with retractions or fibrosis, for we have often been able to obtain, without much difficulty, a complete and immediate reduction.

In one case the irritative material consisted of small particles of bone, separated from the neighboring bone, on which could be seen a slight irregularity

at the point where the bullet came in contact, and the resulting periostitis. This slight lesion had escaped the observation of the roentgenologist.

Similar findings have occurred in a sufficient number of cases to show that this is not a coincidence. They are of interest as they indicate one way by which organic and functional contractures may start. They are also of interest in explaining certain cases in which the *x*-ray does not reveal anything. There is good reason to believe that non-metallic foreign bodies or non-osseous substances would escape discovery by the *x*-ray, but may cause similar contractures, either by irritation of nerve filaments or muscle fibers. It is also possible that

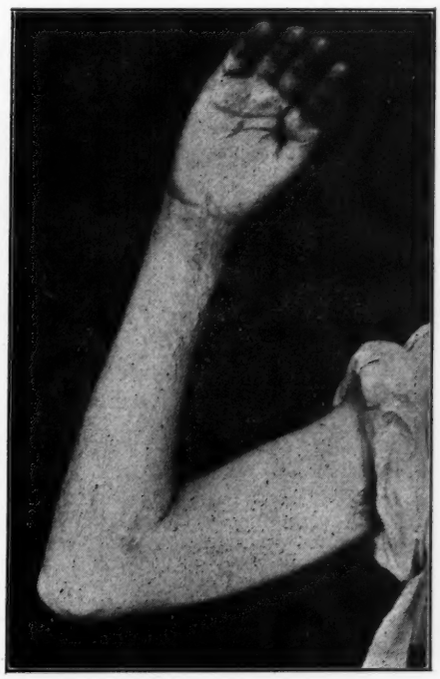

Fig. 4. Contraction of the forearm on the arm, after wound of biceps. This was due to small fragments in the biceps as shown by the roentgenogram.

small scars, even very small, can act as foreign bodies in the same way without, by their presence, interfering with motion.

In a certain number of cases, much less common, the irritation is of the nerve itself. The wound is at a distance, sometimes a considerable distance from the contracted muscle. There is further confirmation in the belief that it is a purely functional affair, in that one muscle alone, or a small number of muscles, supplied by the irritated nerve, are affected. We know today by physiological experiment and the electric experiments on man, by Pierre Marie and Meige, that the innervation of a muscle is individualized on a certain portion of the circumference of the nerve trunk from its origin. We can therefore conceive that the localized irritation of a nerve can produce effects, at a distance, on certain groups of muscles, or individual muscles themselves.

Here is an example of a case of limited contracture due to nerve irritation at a distance: Patient, wounded December 21, 1914. The bullet entered between the middle of the spine and the left scapula. It was removed a few days afterwards, on the superior border of the sterno-cleido-mastoid muscle, two fingers' breadths above the left clavicle. The left arm stayed inert for ten days or so, then the patient began to be able to move it. When he came to the neurological center, certain movements were still incomplete—extension and flexion of the forearm, extension and flexion of the fingers, etc. At the present time, all motions are about normal, except one,—extension of the forearm. This extension is limited by the contracture of one muscle alone, the long supinator (figure 8). This contracture developed about three weeks after the wound. Since then it has persisted, making a ridge along the ex-

Fig. 5. Contraction in flexion of the forearm on the arm. Small fragments in the muscle.

Fig. 6. Contraction of masseter after wound of left cheek. *X*-ray examination showed a trail of metallic fragments in the muscle.

ternal border of the forearm, limiting the extension of the forearm to a right angle, going into a spasm at all attempts at passive extension, and being an insuperable obstacle to extension, more so even than could be found in a characteristic musculo-tendinous retraction.

Offhand, however, this isolated contraction of a muscle, distant from any wound, seemed to be entirely functional, but at the level of the extraction point of the bullet, that is, approximately at Erb's point, palpation reveals a hard mass, probably of bone, which appears to be more or less adherent to the vertebrae, and roentgenographically appears to be the callus of a fractured rib which has moved upwards. The contracture of the long supinator thus becomes explicable. It is quite evident that at Erb's point, pressing against one of the upper roots of the brachial plexus, there is a permanent cause of irritation.

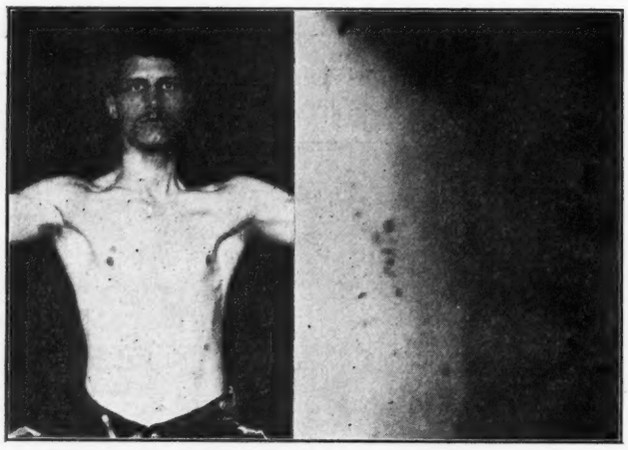

Fig. 7. Contraction of paravertebral muscles following wound of the neck, absolute rigidity developing. *X*-ray examination showed minute metal fragments in the muscle to be the cause. Ultimately cured without operation.

Without a careful examination, this limited contracture, so far from the wound, would have been considered of purely psychopathic origin.

A third variety of contracture of organic origin should be well known. It is of those which occur in all, or some of the muscles antagonized to paralyzed ones. This does not necessarily mean retraction of these antagonistic muscles, as was believed. The possibility of reducing the contracture and the movements produced by electric current, demonstrate this.

At first there is only a difference in tonicity, then little by little the contracture develops, and the attitude of the limb becomes entirely different from that of simple paralysis. In most cases it occurs in the hand, almost always in a musculo-spiral paralysis; this is probably due to the fact that normally the flexors of the hand are much stronger than the extensors. The fingers become flexed in the hand, particularly at the level of the first and second phalanges. The hand takes the attitude of a closed fist with the thumb on the outside. Because of the flexion of the fingers, which separates the points of insertion of the extensors, the wrist is lifted, sometimes even higher than the horizontal, particularly if the radial paralysis is not complete; this pulled up hand, this closed fist, often rigid (figure 9), does not at all give the appearance of the falling hand, extended fingers, of the classical musculo-spiral paralysis.

It can be conceived that the progressive new attitude tends to occur at the time when the radial paralysis begins to improve. This is what we have seen most often. It also is liable to occur if a permanent irritation, such as a musculo-cutaneous adhesion at the level of the wound of entrance or of exit, acts on the flexor muscles.

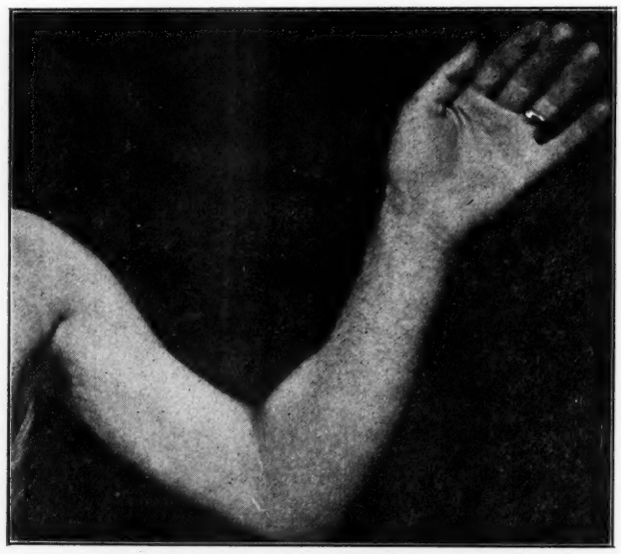

Fig. 8. Contraction limited to the supinator longus. This was due to the irritation of the brachial plexus by rib fracture, resulting from a bullet wound.

In certain cases of musculo-spiral paralysis, not all the flexors are involved in the contracture. Thus one may see the first phalange extend gradually as the musculo-spiral nerve recuperates, but the hand stays flexed, incapable of any extension. It is just the opposite of normal recovery from musculo-spiral paralysis. Passive extension of the wrist is quite as impossible as active extension. One has only to feel in the flexor surface of the forearm the cord made by the contracted muscles to appreciate the cause of the anomaly.

In the lower limb, similar conditions may occur; for instance talipes equinus, hard to reduce, will develop on a flaccid foot-drop due to paralysis of the

external popliteal. In this case again the predominating action of the antero-external muscles plays a part and it is nearly always at a late period that the contracture occurs.

In all these cases, without a careful examination, the anomaly of the attitude might be taken for a purely functional contracture.

What makes it essential to differentiate these various groups of contractures and pseudo-contractures is the fact that their *treatment* is essentially different.

As far as the purely *functional contractures* are concerned, we don't have to go into the various methods of psychotherapy and the faradic current which, in a short time, will clear up contractures in the "obstetrical hand" attitude. In military neurology we are, however, in the presence of a certain amount of resistance that we do not meet in civil life, even in compensation work, and it is due to the small desire the patient has got to get well, even when he has not imagined his sickness. In these cases, isolation, in separate rooms, or if not practicable in booths, does wonders. It isolates the patient from the outside world where, as we know, charitable souls have a predilection for neuropathics and malingerers, not only the most interesting of the war, but often the torment of the doctors.

Fig. 9. Contraction in flexion of the fingers with extension of the wrist in a late sequela of musculo-spiral paralysis.

Among the various functional contractures, there is one that I wish to mention, because I have often seen it in malingering and in nearly every case it is purely simulated. This is: contracture, in extension, of the leg. These can be done away with, right away, in most cases by force and tenacity, using the leg as a lever and the foot of the bed or your own knee as the fulcrum. Once the contracture is overcome, the patient convinced, the knees remain easily flexible. Disciplinary measures are all that are necessary to keep up the cure. I have yet to see such a contracture recur.

Of more interest is the treatment of contractures due to *organic causes*.

For contractures close to a wound in the neighborhood of the contracted muscle—in the majority of cases—contractures in flexion of the arm or leg we proceed thus: The roentgenograms having revealed to us, in a large number of cases, the presence of foreign bodies, we have the patient *x*-rayed. If a rather large foreign body is present, the best policy to follow is of course to remove it. In the majority of cases, however, there is more likely to be found metallic dust. Theoretically we should remove it, but nearly always this is impossible, and besides we have cured many of these contractures medically, in spite of the presence of even fairly large foreign bodies. The first thing we do is to try to reduce the contracture at once; to do this, we attempt to extend the limb, by slow traction, very progressive and without any sudden jerks. If reduction is too painful, we make use of the Esmarch bandage, which generally decreases the rigidity; sometimes we give injections of cocaine, along the path of the missile and especially in the region of the tendon. When the patient consents to general anesthesia, which is exceptional, this is still better.

Fig. 10. Patient of figure 4, wearing the apparatus for ambulatory treatment of flexion contracture of the forearm by graduated extension. The patient was thus cured.

Very often while the attempt is made to extend the limb a tactile (and sometimes auditory) sensation is felt as if pressing on snow, which indicates the rupture of fine adhesions between the skin, aponeurosis and muscle, or even in the muscle itself.

It is worth noting that similar sensations are felt in really functional contractures far from any wound, which proves that a constant posture, even if neuropathic, can lead to the formation of adhesions after a certain length of time. The patient is really unable to stretch the flexed limb, and the Esmarch bandage is also unable to relax the limb. Therefore, as we have said previously, we do not consider that the Esmarch bandage test is very conclusive to differentiate true from false contractures.

Even when the Esmarch bandage has not accomplished any results, however, it is possible to obtain complete extension of the limb, and this may be permanent. When the limb is entirely extended it is immobilized in a splint for three or four days. When the splint is removed, it is not rare that the extension remains permanent, even when the contracture is manifestly caused by small foreign bodies and the reduction was accompanied by characteristic crepitations due to adhesions.

In a great number of cases immediate reduction fails, even with anesthesia or, if obtained, it lasts only as long as the splints are kept in place. In these cases we are not inclined to paralyze temporarily the nerve by injections of alcohol, as suggested by Sicard. Without considerable experience we fear to paralyze it permanently. I believe it more advisable to proceed by slower and progressive methods, by gradually extending the muscle and getting it used to the irritation of the foreign bodies; in other words, to practice a real muscular re-education.

In this respect, mechano-therapeutics methodically applied and repeated every day, or several times daily, always done without undue pulling or any sudden movements, give nearly always very good results. We are surprised to see that several writers consider this detrimental. The apparatus of Privat, consisting of a rope, a pulley and a weight, is particularly useful. In one or two months we have obtained extension, nearly complete, of a forearm or leg, which previously was irreducible and seemed to be justified by the presence of foreign bodies. But in this treatment a certain factor plays a tremendous part; that is, the good will and to a certain extent the intelligence of the patient. It was among the officers and non-commissioned officers that we obtained the best results.

If daily traction, for a certain length of time, is so encouraging, certainly continuous traction should be very beneficial. We have applied it with fair success in cases where keeping in bed and relative isolation have had an effect in restoring co-operation as well as on the muscular contraction itself. In other cases we have deemed it advisable to apply continuous extension, without necessarily keeping the patient bedridden. It is for these cases that we had made various apparatus, cheap and rather simple, which allowed real continous extension while still allowing the patient to walk about (figure 10).

These consist of two splints made of tin, which are laced in place, one to the arm, or to the thigh, the other to the forearm, or to the leg on the side of flexion. The two splints are united by two lateral hinges, similar to those of medieval armors. They are also united on their free surface by a screw which engages a toothed wheel. After putting the apparatus in position, so that the limbs are extended as much as possible, every day or every second or third day, the wheel is turned one notch, thereby stretching the limb further. So placed, the apparatus not only allows one to graduate the continued extension but enables one to judge the progress. This can be put down in figures, by measuring the distance between the furthest points of the two splints.

We have not as yet sufficient experience in these apparatus to judge of their value, but we do not doubt that they will give good results, at least as good as extension of the limb in bed.

We consider that tenotomy should be resorted to only as a last measure in rare cases. As for the treatment of *contractures due to irritation of nerve trunks*, we have very little to suggest. The only logical treatment is the removal of the irritation whenever possible; thus we are going to have the bony mass removed in the case of irritation of the brachial plexus, causing the contracture of the long supinator.

For contracture of muscles antagonistic to the paralyzed ones, a remark is necessary. It occurs nearly always, when the treatment has not sufficiently isolated the paralyzed from the non-paralyzed muscles. For instance, in musculo-spiral paralysis if all the muscles of the forearm are massaged, instead of massaging only the extensors; or again in using the faradic current, the affected muscles are not stimulated, because they are not susceptible to stimulation, while the healthy antagonistic muscles are; or again by the use of the application, in baths, of galvanic current (a method necessitated by its convenience in a heavy war service) the sick muscles are stimulated, but so are also the healthy muscles which already had a marked preponderance.

These remarks justify these rules in treating peri-

pheral nerve paralysis: never massage non-paralyzed muscles; never employ faradic current; use only galvanic baths as a last resort, and, in every case, if contracture does occur, apply only galvanization with plates and so feebly that there will not be diffusion of the stimulation to the non-paralyzed muscles. We may also add that contracture is most liable to occur in non-paralyzed muscles when the limb is left to it elf without any mechanical support. Therefore, the various mechanisms that lift up the hand or the foot, in musculo-spiral or sciatic paralysis, particularly those with elastic traction (rubber, or better still, metallic springs) appear to us as important preventive measures against late contractures.

The few types of cases here discussed are not the only ones to be found following wounds of the extremities; they show that if, with little experience, we can sometimes diagnose at once certain purely functional contractures, in the majority of cases we must make a diagnosis of purely functional, or psychopathic, or hystero-traumatic origin with a great deal of reserve, the *x*-rays often showing a point of irritation of organic origin. These cases must also show, leaving aside the problematic action of certain drugs, that the treatment must vary according to the cause of the contracture. This I believe justifies a careful study of each particular case.

REPAIR OF LOSS OF BONY SUBSTANCE AND RECONSTRUCTION OF BONES BY OSTEO-PERIOSTEAL GRAFTS TAKEN FROM THE TIBIA. (WITH 118 NEW PERSONAL CASES).

GENERAL HENRI DELAGENIÈRE.
Chief Surgeon, French Army.

The idea of repair of losses of bony substances by periosteal bone grafts is old and is due to Ollier. He reported a case of transplantation of a piece of tibial periosteum under the skin of the forehead, to remodel a nose. The operation was performed May 13, 1835. The periosteum was removed from the bone, the skin of the forehead elevated and the graft introduced underneath. There was suppuration and because of the fear of possible erysipelas, the piece of periosteum was removed. When this was done it was found to be adherent at several points, and therefore was beginning to grow.

Ollier did not attempt this again and from then on tried to remake noses by means of strips of periosteum adhering to mucous membrane or bone, without trying to establish a general method for bone reproduction. In other words, he conceived a method, but was stopped by the danger of infection which could not be avoided in those days. Instead of an osteo-periosteal graft, he attempted a simple periosteal graft, and tried to reconstruct the skeleton of the nose, without attempting to reconstruct a portion of a bone.

This case was nevertheless the first of its kind and has been the start of all the attempts that I have made to reconstruct bone. I am therefore very pleased to be able to honor here an old master, who was good enough to favor me with his friendship, honor due to a discovery which, when modified by modern medicine, has afforded relief and cure to a large number of wounded people.

The failure of bone-grafting as done by Ollier, seemed to be the result of two factors. First, by removing a strip of periosteum with a chisel a certain number of osteogenic cells were left on the bone; secondly, the transplanted piece of periosteum was not under normal physiological conditions and its osteogenetic properties were interfered with. For this reason I take with the periosteum a strip of bony tissue in which all the osteogenetic cells will be found. Furthermore, this strip of bone, by its presence helps to keep this periosteum spread out and make it more easily adapted to the various places it must grow upon.

I therefore take, on the internal surface of the tibia, an osteo-periosteal graft, that is the periosteum, attached to a layer of bone, and transplant it to the place it is to be grafted upon. But remembering the elimination of the graft of Ollier, I perform the first graft in two stages.

CASE I. A female of 14. who had the nose completely destroyed by lupus and had several operations to remove the damaged tissue.

November 29, 1905, by means of the chisel and mallet I removed an osteo-periosteal graft on the internal surface of the tibia (left). This graft measured 9 cm. in length and 2 cm. in width. It was left adherent to the bone towards the upper end of the tibia. The skin over the tibia was sutured in such a way as to allow the graft to protrude. A tunnel was then prepared on the anterior surface of the left forearm and the graft introduced in it. The forearm was kept in position by means of a plaster cast.

December 13, 1905, the pedicle of the graft was cut and the small wounds of the tibia and forearm sewed up.

The graft took on considerable growth. An Italian graft was made on the 26th of March, 1906, with the skin of the forearm containing in it the osteo-periosteal graft. The first stage was performed on the 26th of March, the second on the 5th of

April, 1906. When the graft was separated it was bent and planted in the lip until the bony contact was established.

On November 21, 1906, the patient came back because the nostrils had become obstructed. The graft had taken and was very solid. Two openings were made in the skin that closes the nostrils, and an epidermal skin graft, curled around a small drain, were introduced into the openings.

The patient returned December 10, 1906. She was doing well and breathing through the nose which unfortunately had proliferated and was too large.

This case therefore gave a complete result as far as the graft was concerned, but the difficulities in performing the graft in two stages, decided me to attempt direct transplantation, as in the two succeeding cases.

CASE II. A female, 21 years old, had her nose completely destroyed by a lupus which had been treated by Finsen rays in Paris.

February 6, 1907, cleansing of the nose and extirpation of all the mucous membrane; then an osteo-periosteal graft 7 cm. long and 15 mm. wide, was introduced in a subcutaneous tunnel, made in the left forearm, to furnish a skeleton for the nose.

March 13th, first stage of an Italian graft with the skin of the forearm containing the graft.

March 22nd, second stage; the graft separated from the forearm with skin, then bent and fixed at the base.

The immediate result was fairly good as far as the graft was concerned, which took well, and was solid, but the reconstructed nose was irregular in appearance.

This patient was seen again October, 1917. The nose was hard and solid, the graft held well but the nose was deformed. No recurrence of the lupus.

CASE III. Man, 30 years old, presented a pseudo-arthrosis of the left radius, resulting from an old fracture of the middle third.

March 31, 1906, opening of the arm, freshening of the bony extremities, to a length of 2 cm., introduction of a sterile nail in the medullary canal so as to keep them more or less in contact, then an osteo-periosteal graft taken from the tibia, 8 cm. long and 20 mm. wide.

This graft was then applied around the bony extremities, the proliferating surface on the bone. The tissues were sutured on top of the graft and the skin brought in apposition. Perfect cure.

The patient came back June 11, 1907, with a solid radius and able to pronate and supinate.

These three observations show that an osteo-periosteal graft can be transplanted in any tissue to live and take up its osteogenetic functions.

From this period on I have had recourse to osteo-periosteal grafts in all cases of pseudo-arthrosis in which I have had to operate.

The bone injuries in the war wounded have offered me many occasions to apply these grafts.

Loss of skull substance in trepanation, loss of bone in the face, loss of mandible, pseudo-arthrosis with, or without, loss of part of the long bones, flail joints, resulting from too extensive resection of the knee, etc., can be cured by this method. Furthermore, it can be applied to a good many other conditions as can be seen in the subsequent report.

The graft must have the thickness of a ten-cent piece; it must never consist of the total thickness of the internal surface of the tibia.

It consists of a periosteal-bone graft lined throughout its whole length by a thin layer of bone, whence the name, *osteo-periosteal graft.*

The bony layer is essential to give consistency to the graft, to keep the periosteum stretched, to keep it in its physiological condition, so that its osteogenetic functions can continue normally.

To obtain the graft all that is necessary is a chisel and a mallet. The internal surface of the tibia is exposed by a longitudinal incision, care being taken not to injure the periosteum. On this internal surface, by means of a scalpel, the outlines of the grafts are made out, one under the other. In this way, one, two or three grafts of five, six, twelve centimeters length are outlined, thus utilizing all the inner surface of the bone, if need be.

When all the grafts are thus outlined, the chisel follows these lines, penetrating well into the bone. It is then inclined obliquely, nearly parallel to the internal surface of the tibia and the osteo-periosteal layer is removed, exactly as a carpenter removes a wooden chip. The chisel must not be inclined too much, for fear of leaving a portion of periosteum without any bony lining, neither must the chisel be held too much in the perpendicular, in which case the medullary canal might be penetrated and the graft be too thick, besides causing an unnecessary lesion of the tibia.

When the grafts are separated, they take the appearance of thick chips of wood. They are rolled up on their periosteal surfaces and are elastic enough to be pleated, bent, curved or modelled according to the position in which it is desired to place them. They are then placed in the wound where a bed has been prepared for them, and are carried thereto on a sterile compress.

To obtain good results it is necessary to observe the following rules, which apply to all osteo-periosteal grafts:

It is absolutely necessary that the graft be in contact with living tissue. On the skull this condition is easily obtained, the two surfaces of the graft are

in contact with layers of tissue, very vascular and without any spaces between, and this is the reason why in plastic work of the skull results are the most rapid and most constant.

By living tissue, we mean tissues as near normal as possible and preserving all their vitality. We must therefore remove with care all sclerosed tissue so that the graft will be in as physiological a condition as possible. In certain cases it is necessary to leave cicatricial tissue in order to avoid opening infected cavities; in these cases the graft may take, but the result will be much slower and less perfect.

Antiseptics must be omitted entirely, but of course absolute asepsis is essential.

Finally, there must be no dead spaces where blood might accumulate and form hematomata which might secondarily become infected. This question of hematomata is very important, for it is to this condition that most of our failures are due. Hemostasis must be as complete as possible. Then the grafts are covered over with a thick layer of tissue well sutured over the graft with catgut stitches. In this way all dead spaces are avoided as well as blood effusions.

This has also the advantage of holding the graft in place, which is absolutely essential, until the various apparatus are applied to immobilize the part until the complete consolidation of the graft.

These principles being outlined, I shall now describe the operation itself.

The operation consists, for each variety of bone graft, of the preparation of the bed for the graft, the operation on the extremity, the placing of the graft in its position, the closure of the wound, the keeping together of the bony surface during the growth of the graft and the formation of new bone.

I. CRANIOPLASTIES. The wound must have been completely healed and the integuments sufficient to cover the graft and the operative field after removal of all subcutaneous cicatricial tissue. It is necessary to make use of the scar, whatever its condition be, and to open the field of operation just as one would for a simple cutaneous autoplasty. One therefore makes a longitudinal incision, stellate incisions, or a trap-door flap, as may be indicated. Each cut through the cicatrix is made by two incisions converging in the depth, so that each margin is feather-edged and can be more easily sutured without rolling up. The incision having been made, the skin flaps are raised, chiefly by peeling back, far enough to provide that the wound can be easily closed without tension. The two, three or four flaps are then covered with compresses and turned aside. There now remains in the center of the wound a star-shaped or linear cicatrix which one dissects with care from the deeper tissues and removes completely.

When the field of operation is thus exposed, the opening to be closed by the bone graft is explored with the finger. In most cases it consists of the opening of a trepanation, either round, or oval, and occasionally irregular. The pericranium around the opening is incised down to the bone with a scalpel and is pushed back 2 or 3 cm. all around the opening. It is in this space that the bone grafts are placed and it is this raised periosteum which will hold them in place. All bleeding is controlled. The wound is covered with gauze tampons while the graft is being cut from its source, as above described.

Placing the bone grafts in position is very simple. They must be placed one next to the other, like a parquet flooring. To obtain solid ossification in a short time, it is necessary that the bone grafts should be in contact with each other, or better still, slightly overlapping. Unless there is some contraindication, the proliferating bone surface must be placed on the exposed tissues and therefore on the brain, the periosteal surface in contact with the pericranium. This has the following advantages: The osteo-periosteal graft takes contact with the bone by its proliferating surface, and becomes solidly fixed, furthermore the graft presents its periosteal surface to the overlying tissues and does not adhere to it and the scalp is then easily movable over the bone graft.

At first I used to place the proliferating side of the graft externally because of the fear of the bone graft beginning to proliferate and cause pressure on the brain and irritation of the meninges. But such proliferation of the bone graft is not a thing that happens very often and it seems fairly easy to be able to avoid any such accident.

The only cases in which I found it necessary to place the grafts on the wrong side, so as to prevent any possible irritation on the brain from the bone graft are:

1. When there is a hernia cerebri. 2. When there are symptoms of Jacksonian epilepsy, in which the cause is not found during operation to be due to a piece of bone, or a thick scar adhering to the brain, or in which the cause cannot be removed. 3. In subjects below 20 years of age, who have been found to have proliferation of the bone graft more frequently than others.

The skin flaps have been previously prepared so

as to unite very closely. All that is necessary, therefore, is to bring them together, care being taken not to move the bone grafts which are kept in place only by their covering of pericranium.

Drainage is not absolutely necessary, it can be omitted if the dressings are changed every day for the first four or five days following the operation. When this is impossible, it is best to drain and put on a dressing which may be kept in place for four or five days after the operation. After this the drain can be removed and a second dressing applied which may be kept on to the ninth or tenth day after the operation, at which time the sutures can be removed. The wound after this need be protected only by a slight dressing.

Position in which to place the patient. If the bone defect was considerable and the wound is old, and when there is loss of cerebral tissue, there exists prior to the operation a considerable depression which must be done away with. In these patients, the depression is increased in the vertical position. In the horizontal position, this depression decreases and occasionally disappears. It is therefore logical to place the patient, after operation, in the horizontal position, even with the head slightly lower than the rest of the body and to keep him in this position until the bone graft has become solid. This procedure has given me excellent results, especially if, while applying the bone grafts, care is taken to model them to the shape of the skull.

After a fortnight the grafts appear solid, but it is best to keep the patient recumbent with the head low for another two weeks.

II. PSEUDO-ARTHROSIS OF THE MANDIBLE WITH LOSS OF BONE. This condition necessitated considerable investigation, but I now consider the problem solved. By means of osteo-periosteal bone grafts, it is posible to cure any pseudo-arthrosis of the lower maxillary and fill up any loss of bone. But in this condition it is also necessary to have recourse to specialists. After operation, it is necessary that the bone grafts be kept in position by means of splints inside the mouth, which are to be kept there until complete consolidation. The apparatus is placed in position during operation, but as soon as the patient wakes up and stops vomiting, the jaws are immobilized by wiring the splints.

This apparatus is sufficient to keep the maxillary bones in good position and the periosteal proliferation is sufficient to fill up the loss of substance and form a bony mass which will allow the patient to chew and to wear false teeth, if necessary.

It is therefore absolutely unnecessary to have recourse to metallic plates or metallic sutures as I used to do. All these pieces of metal are foreign bodies and must eventually be removed in the majority of cases. They are more of a hindrance than a help to a bone graft and I have stopped using them.

Exposure of the bony extremities and preparation of the grooves for the bone graft. Previous to the operation, the mouth of the patient must be in good condition. I use, if possible, the existing scar to expose the bony extremities. The scar is the result either of the original wound or of a primary attempt at a plastic skin operation. In these cases more so even than others, it is necessary to cover the wound with a layer of viable and freely movable integument. As in cranioplasty the scar is circumcised by two converging incisions, cutting the skin obliquely, so that the flaps can be sutured without rolling up the skin. The flaps are dissected up far enough to allow them to be brought together on top of the grafts without any undue stretching.

To keep the ascending ramus of the mandible in position caused me considerable worry at first, and this is the reason that I used to employ metallic plates, screwed tightly in the two pieces of bone, but experience has shown me that this is of little importance, even when the end of the bone projects in the mouth. All that is necessary is that the bone graft comes in contact with an exposed end of bone to make a solid mass. When this bony mass is well established articulation of the mandible re-establishes itself, whatever the position of the condyle.

When the wound is exposed, the position of the two bony ends is determined as well as their relation to the mucous membrane. It is absolutely necessary to avoid opening the mucous membrane for fear of infection of the bone graft.

The finger of the assistant is introduced into the buccal cavity and is made to follow the deviations of the ends of the bones. In this way tearing of the mucous membrane is avoided, which is essential in order to avoid the introduction of bacteria in the field of operation. Once the positions of the ends of the bone are known, an incision is made in the soft tissues, between them. The ends of bone are liberated for an extent of about 2 cm., if possible, so as to allow of placing one graft behind or below, and a second on top of each end. Following then the previous incision, an attempt is made to cut out two flaps 1.5 cm. each, so as to introduce, in their place, the graft which will bring together the two extremities of bone.

All bleeding points are then controlled, so as to avoid any possible hematoma. Then the wound is tamponned while the graft is being made.

Two grafts are all that are necessary for a simple loss of bone of the horizontal ramus, whatever may be the length of the gap. Three or four bone grafts are necessary, if it is desired to reconstruct the angle of the inferior maxillary, that is two for the horizontal and two for the vertical ramus. These four grafts are interposed, perpendicularly, to make the angle, and so as not to displace them it is well to transfix them with a double catgut ligature on each side of the bone graft.

Each bony end must be placed between two bone grafts, each graft must have its cut surface on the bone so that the two bone grafts adhere to each other by their inner surface. If four bone grafts are used to remake the angle of the jaw, the two vertical pieces are placed with their inner surface on the superior extremity of the ascending ramus, then the two horizontal pieces on the anterior extremity, the inner surface always contacting with the jaw bone. At the angle the pieces are placed without paying much attention to the inner surface and then are tran fixed with a double strand of catgut. The grafts are covered by flaps of soft parts sutured over them. Finally the skin is brought together and sutured with interrupted horse-hair stitches, attempting to obtain as regular a scar as possible.

As in the case of the skull, drainage is not necessary, if the wound can be watched. As a protective dressing gauze with a little cotton is all that is necessary. This dressing is changed every time it is soiled and the stitches are examined carefully to avoid any possible stitch abscess, removing any suspicious stitch that appears to be causing irritation, evacuating any stitch-hole secretion and, if necessary, inserting a skin clip to replace the suture.

Post-operative care is very simple; the patient is placed in bed and allowed to react from the operation as any other patient. When he appears to have finished vomiting and to have recovered from the narcosis the two parts of the dental splinting apparatus are brought together with silver wire. The apparatus brings the two jaws into proper occlusion and it is in this position that consolidation takes place.

The apparatus is kept in place for 30 months. Union takes place earlier but under no condition must the mandible be set free without being sure that there is complete consolidation. In certain cases it takes a very long time before the bone becomes solid enough. In some of our patients it took more than a year.

In our first patients, we believed that our results had not been satisfactory when as a matter of fact there was only delay in the process. This was particularly noticeable when there was a slight infection of the wound. This shows that slight infection does not interfere absolutely with the growth of the bone graft; it of course is detrimental, but unless the bone graft has been completely destroyed it will finally proliferate and give the result desired.

This observation is important, for we must not consider a delay to be an absolute failure.

With this technic, bone grafts of the mandible give satisfactory results and failures are rare.

III. PSEUDO-ARTHROSIS WITH LOSS OF SUBSTANCE IN LONG BONES. The technic is the same whether we are dealing with a simple pseudo-arthrosis or one with loss of substance.

The procedure is as for the maxilla. The skin must be dissected as in a plastic operation, for it is necessary that the wound be covered with flaps that are viable, movable and free from tension on the sutures.

The bony ends are denuded and freshened. The bed for the bone graft is made carefully and enough soft tissue is left so that it can be closed above the grafts. It is necessary that the grafts extend at least 2 cm. on the ends of bone and these ends must be placed between two bone grafts, with their proliferating surface on the bone.

An extra graft can also be put in between these two, but this has very little advantage. I am satisfied to use two bone grafts even to reconstruct a considerable loss in a thick bone, such as the tibia.

If we are dealing with a simple pseudo-arthrosis without any loss of substance, I simply wrap one graft like a ferrule around the bone ends, well denuded and freshened, and I keep this bone graft in place by means of a piece of catgut. But in this case I am careful to cushion the soft tissues around the graft to keep it snug against the bone.

When the two grafts have been placed in the beds prepared for them, they are covered over with the flaps made of the soft tissues, sutured with catgut. The skin is sutured with horse-hair.

To keep the bones in good position I use a plaster cast, applied with the limb in the best position for union. For instance, for the bones of the forearm, the limb must be supinated and the elbow must be included in the apparatus. For the arm, the limb must be abducted and the plaster must include the

thorax. For the leg, the foot is slightly abducted and the knee must be included in the plaster. For the thigh, the limb must be placed in abduction and the apparatus come up as high as the thorax.

The plaster casts are changed every month so as to correct as best as possible any deformity which the leg may have taken. These must not be entirely corrected until complete ossification. Ossification will take much longer in cases in which large quantities of bone substance have been lost. Sometimes it takes as much as eight to ten months to get good union and a strong bone.

IV. CLOSURE OF BONY CAVITIES. If we are dealing with bone cavities sterile and healed as we often meet with in the upper or lower epiphyses of the tibia, or in the condyle of the femur, the task is sometimes rather difficult because of the fragility of the bone which is often reduced to a shell. Cavities are also sometimes found in the diaphysis of the long bones.

All these cavities are fairly easy to close by filling with osteo-periosteal fragments. The technic is very simple. The skin is prepared as for an ordinary plastic operation, for the grafts must be well covered. The cavity is carefully curetted, then it is filled up with osteo-periosteal bone grafts, so that there are four or five layers of them. It is not necessary, if the cavity is very large, to fill it up to the brim, for this would necessitate a large quantity of bone grafts. It is more important not to leave any dead spaces between the bone grafts and in order to avoid this the dressings must exert a certain degree of pressure.

Good results can also be obtained in infected cavities in which healing has not occurred. The cavity is curetted, disinfected with hot air, and filled up with osteo-periosteal bone grafts which are covered over with healthy flaps. Healing will be progressive, fistulae will form with elimination of pieces of bone but the final result will be good.

V. BONES OF THE FACE AND OTHER GRAFTS. All the bones of the face can be reconstructed by means of osteo-periosteal bone grafts. All that is necessary is to attach the graft to the region to be made over. Afterwards it can be bent, rolled up, or folded to obtain the desired shape. The bone graft must get a start on a denuded bone. Superficially it appears to be very easy, the tissues are alive, dead spaces are easy to avoid and hemorrhages easy to control. Failures are rare and nearly always due to the opening of a sinus of the skull. The skeleton of the nose can be made over entirely with bone grafts, either directly or indirectly.

Indications for bone grafting are numerous and will increase daily as the operative measures become more familiar.

The evolution of bone grafts is easy to follow with the *x*-ray. They can be seen becoming thicker and therefore more opaque. It can also be seen that the bone grafts proliferate bone tissue which unites with the osseous host and becomes the starting point for a new bone.

The bone grafts may become too exuberant in young adults. It is not a rare occurrence but is important only in work on the nose. This excessive proliferation was the reason that I used to place the proliferating surface externally in cranioplasty, for fear of irritating the brain, but I realized that this fear was exaggerated, and I now place the proliferating surface towards the brain.

As to absorption of the graft I never have seen it. If there was elimination of the bone graft, the results would certainly not be as good, but would not be absolutely unsatisfactory. The bone produced will be less solid and thinner, but it will be there nevertheless if the elimination has only affected the bone itself, leaving the periosteal layer. This will continue its osteogenetic function and will finally produce enough bone to obtain the necessary result.

The wound in the leg is insignificant. It will close by first intention, but it is best to drain it to avoid hematomata. I have never seen any severe complications from it. Occasionally small abscesses are formed, due to elimination of small fragments of bone. As a rule the wound heals up within a week.

My series of 118 cases* gave me the following results:

Fifty-two cranioplasties with 44 very good results, 7 good results and 1 unsatisfactory result from elimination of the bone graft. In this case the operation was repeated and good results were obtained.

Twenty-seven grafts for pseudo-arthrosis of the mandible, with loss of bone tissue, gave 10 very good results, 7 good results (not yet entirely cured), 2 satisfactory results, 3 partial results, and 5 bad results.

Twenty-one bone grafts for pseudo-arthrosis, with loss of bony substance in long bones gave 15 good results, 3 partial results, in which 1 has a second pseudo-arthrosis necessitating a second operation; 1 gave no results because of complete elimina-

*Since this paper was written the number of osteo-periosteal bone grafts that I have performed is now 272 with good results in nearly all the cases.

tion of the bone graft, 1 died from septicemia (epileptic who would not do what he was told) three months after operation.

Three bone cavities with 3 successes.

Sixteen bone grafts for reconstruction of the face with 14 good results and 2 incomplete results.

One bone graft for cure of hernia, result so far unknown.

THE OPERATIVE CORRECTION OF LONG-STANDING ERB'S PALSY.

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This paper is presented with the idea of bringing before the medical profession the facts that Erb's palsy or "obstetrical paralysis" can and should be treated so as to minimize subsequent deformity and disability. In the majority of cases the patient or parents are told that nothing can be done. This is not true and either the teaching of the medical schools is at fault, or the student's memory is poor.

What, then, is obstetrical paralysis? It is a paralysis of the arm, either partial or complete, usually due to a forcible labor, a big baby, a small pelvis, anesthesia, forceps, and generally a head delivery with the shoulder caught behind the pubes. With the above combination, force applied wrongly so as to separate the head and shoulder will often result in an injury to the brachial plexus.

The most common injury to the plexus is a tearing of the suprascapular nerve, as well as a tearing or fraying out of the fifth and sixth cervical segments where they come together, which junction is known as Erb's point. This results in a paralysis of the outward rotators of the arm, as well as the deltoid and triceps and supinator longus. In time, many of these muscles regain most of their strength, except the outward rotators, such as the supra- and infraspinatus and teres minor. Meanwhile, the internal rotators, such as the teres major, the subscapularis and the pectoralis major, which is also an adductor, become contracted because unopposed by normal muscles, and the condition of the arm then is as described below. Certain cases, if taken early, and placed on a splint in the abducted, elevated, outwardly rotated position, gain rapidly through massage and exercises. Others, even with good treatment do not do well and develop contractures. In fact, all cases develop contractures because of interrupted treatment.

Certain cases, more particularly the older ones, say from five years up, develop a varying amount of posterior subluxation of the head of the humerus, due to the persistent, unopposed pull of the contracted subscapularis and teres major. This subluxation may be accompanied by a certain amount of acromial deformity, consisting in a bending down and forward of the end of the acromion, which is unopposed by the head of the humerus in its normal position. This acromial hooking may be severe enough to interfere with the proper reduction of the head of the humerus in the glenoid cavity, and an osteotomy has to be done upon it to lift it out of the way.

All cases eventually have more or less inability to fully and freely supinate, and a small number develop later a subluxation of the head of the radius which may lead to its resection.

The patient generally presents an arm with the following conditions: There is inability to elevate and abduct the arm at the shoulder,—rarely can the arm be raised to or above the shoulder level when abducted. There is definite passive and active limitation to abduction and outward rotation. There is active limitation to supination, which often can be fully performed with the elbow flexed and the arm at the side, but almost never can be done with the arm held in as abducted a position as possible, on account of the persistent inward rotation.

There is also inability to put the hand on top of the head or behind it. Often the only way a child can get the hand to the mouth is to elevate the elbow above the shoulder level; it has to be done this way because of the impossibility of outwardly rotating the arm. If one can not outwardly rotate the humerus, it is impossible to get the hand to the mouth without elevating the elbow, because of the persistent inward rotation.

Two types of paralysis are seen: first, the upper-arm type, which results from a lesion of the suprascapular nerve and the 5th and 6th cervical nerves at or about Erb's point. This injury produces a paralysis only of the muscles of the upper arm, with the exception of the supinators. The less usual, second, type, the so-called whole-arm type is the result of any injury not only to the 5th and 6th cervical nerve roots, but the 7th and 8th and possibly the 1st thoracic as well. Here the whole arm is flaccid, there is wrist-drop and paralysis of the small muscles of the hand. Eventually the shoulder muscles partially recover, but the lower arm muscles in the whole-arm type of case practically never do, and the patient is left with a badly crippled arm and hand.

TREATMENT.

These cases at once resolve themselves into two divisions, namely, those to be treated with massage and exercises, principally those of the upper arm type; and those to be treated by operation on the plexus, usually those of the lower arm type. Unless the early treatment has been adequate, the upper-arm type will also come to operation, not for plexus repair, but to correct contraction deformities. This operation, which I have devised, will be spoken of later.

At first, in order to prevent contraction of unparalyzed muscles, it seems best to put the arm at rest in such a position that the muscles cannot become contracted. This may be done by holding the arm in a plaster cast, or by the use of a light wire or aluminum splint, in an abducted, elevated and outwardly rotated position, with the hand supinated.

Fig. 1. Before operation. Note inability to supinate and outwardly rotate.

This position can be maintained between massage and gymnastic treatments, and insures a better subsequent position of the arm. It also takes the drag off the paralyzed muscles, allowing them to regain their strength more quickly, and prevents subsequent shoulder joint deformity, such as subluxation and acromial hooking and overgrowth.

Massage and exercise are of the greatest importance and should be performed daily, if possible. It is most unwise to allow a child to become obsessed with the fact that it has an arm which cannot be used. Exercises that have been described by Dr. J. J. Thomas are most satisfactory, and have been developed during the past twenty years in the neurologic department of the Children's Hospital, Boston. The treatment should be continued for several years at least, and if contractures develop in the subscapularis and pectoralis major, they must be divided before any further range of action in the arm is to be hoped for.

In regard to the operation on the plexus in the usual upper-arm type of case, it might be said that in the experience of the author it has not been found necessary. In the lower-arm type of cases, the situation is quite different, but it cannot be too strongly emphasized that no operation on the plexus will be of any great use in restoring functional activity to the arm, unless contracted and restricting muscles are divided, and careful after-treatment persisted in for a long period.

In regard to the operative treatment on the plexus in the lower-arm type of case, it may be stated that it has been done a number of times without any benefit. The plexus in all cases was found to be so badly torn and so bound down and invaded by scar tissue that any kind of repair was impossible.

The following operation was devised, following suggestions made by Fairbank. It differs from Fair-

Fig. 2. After operation. Note ability to outwardly rotate, abduct and supinate.

bank's operation principally in that the shoulder joint is not opened. Opening this joint leads to adhesions of the capsule, which are troublesome and fatal to the best functional results. In addition, I have found that complete division of the pectoralis major is always advisable, in that it is practically always tightly contracted, and so holds the arm adducted and prevents abduction and outward rotation. The subcapularis tendon can usually be easily found with the arm abducted and outwardly rotated after the division of the pectoralis major, and can be divided without opening the joint capsule.

Operation: An incision is made on the anterior aspect of the arm, beginning at the tip of the acromion and carried down to below the insertion of the pectoralis major. The cephalic vein is found generally in the outer edge of the wound and tied or drawn aside. The tendinous insertion of the pec-

toralis major is defined, raised on an instrument, and divided all the way across the bicipital groove. The pectoralis major muscle is then retracted inward out of the way, giving one a clear view of the axilla and shoulder joint. The arm should now be abducted fully and rotated outward as far as possible.

Following the division of the pectoral, the range of motion in abduction will be found to be greatly increased. Outward rotation will, however, be somewhat limited. With the arm fully abducted and outwardly rotated, the insertion of the tendon of the subscapularis is to be defined. This tendon is inserted on the lesser tuberosity of the humerus at its inner aspect, and its fibers run at right angles to those of the joint capsule, into which they merge. Just below and running parallel to the lower edge of the tendon may usually be found two or three small veins. The tendon of the coracobrachialis obscures

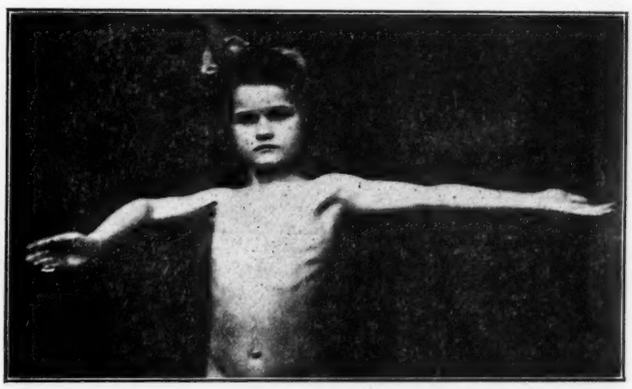

Fig. 3. Mary W. Before operation. Right arm.

the insertion of the subscapularis tendon at times. It is then necessary to separate the origin of the coracobrachialis from the coracoid process by means of an osteotomy, which gives one a much clearer field to see the insertion of the subscapularis. The hole in which the surgeon is working is quite a deep one, and the tendon cannot be easily found unless the arm is in the position above described. The best way to divide the tendon is to pass under it some blunt instrument and so define it. It is of the utmost importance that the shoulder joint should not be opened. The tendon of the subscapularis should always be found, identified and lifted up before it is divided. Blind cuts along the capsule do more harm than good and should never be practised even if, following division of the capsule, the outward rotation is better. Eventually these capsular incisions lead to troublesome adhesions, and the results are never as good as when they are avoided. Following the division of the subscapularis the outward rotation is perfectly free, as well as abduction. If at this stage there is still some subluxation of the head of the humerus which cannot be fully reduced, an osteotomy of the acromion should be done, and the loose distal piece either removed or tilted up so as to allow the head of the humerus to slip back into the glenoid. The wound is then closed with a few deep stitches and a continuous catgut stitch for the skin. No drainage is required. Usually very little bleeding takes place. The arm is then placed on a wire splint, which holds it elevated to or above the shoulder level, abducted and fully rotated outwardly with the hand in full supination. At the end of ten days, massage, baking and exercises are begun, and are continued daily, or at least four times a week. The splint should be worn at night for at least three months and daytimes for at least three months longer.

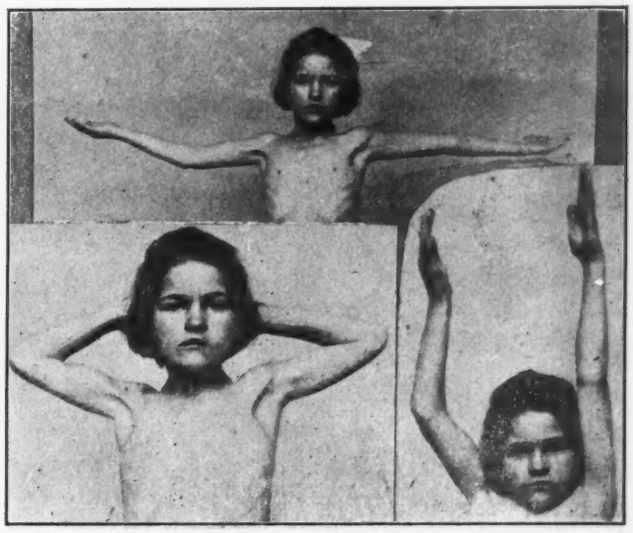

Fig. 4. Mary W. After operation.

The operation merely releases contractions, and gives the stretched and partly paralyzed muscles a chance to recover their tone and strength, and consequently the after-treatment is of the utmost importance. In a certain number of cases it has been found advantageous to divide the pronator radii teres. This muscle is often much contracted and unless released it is a factor in preventing free supination, or tending towards the recurrence of its limitation. This muscle may be easily found and divided by another incision on the upper forearm, subsequent to the shoulder operation.

There have been about 45 cases operated upon now, and in all cases the results are satisfactory. That is, the child has a more useful arm, and the parents are pleased, which while it may not be a surgical factor to be considered is really of great importance in establishing any new method of procedure.

(1) What benefit, if any, has the operation resulted in?

In practically every case that has been operated upon, there has been free and full active outward rotation, as well as increased ability to elevate the arm at the shoulder, depending somewhat on the ability of the deltoid to regain its strength after long stretching and disuse, as well as more persistent residual paralysis in that muscle, which condition cannot be accurately determined beforehand, because of limitation of motion from contractures. Supination becomes either normal or nearly so. The child can get the hand to the mouth easily, can put it on top of the head and behind the head, which in girls is all important, so as to enable them to arrange their own hair. As a matter of fact, after following several hundred cases for several years, outward rotation and supination are never gained by the most persistent exercise treatment, even when stretching under ether is included.

Fig. 5. Catherine H. Before operation. Left arm.

(2) What are the essentials for a successful operation?

A careful operation with free division of all contractures, and the utmost care in avoiding cutting the joint capsule. This cannot be too strongly insisted upon. Fixation in a splint and not plaster, which holds the arm elevated to above the shoulder level, abducted and outwardly rotated, with full supination. Fixation not continued for more than the time required to heal the wound, and then exerci es, baking and massage at least four times a week, wearing a splint for at least six months.

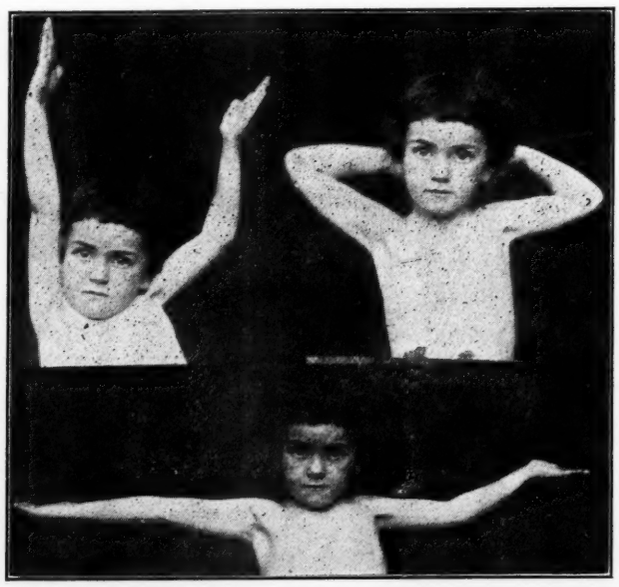

Fig. 6. Catherine H. After operation. Improved ability to outwardly rotate, supinate and abduct.

Fig. 7. Outlines of both acromions from the front. Note acromial hook on right side.

(3) On what cases should the operation be done?

The best results, as we see them, are in those patients who have had previous massage and muscle exercises, and who have some power in the deltoid and supraspinatus muscles. Treatment in all cases should be begun the first week of life, and the arm should be put in the position of physiological rest—that is, abducted, elevated and outwardly rotated

from the first. Children should not have the arm tied to the side or across the chest, as so often is done at first, as this position encourages and develops contractures of the non-paralyzed muscles. Practically all cases, even those that have had no previous treatment, are distinctly improved, but the convalescence as far as active function goes is slower in those cases that have not had previous massage and exercise treatment. Any case that has contractures, even if only of the subscapularis, is better if that contraction is divided. The operation does

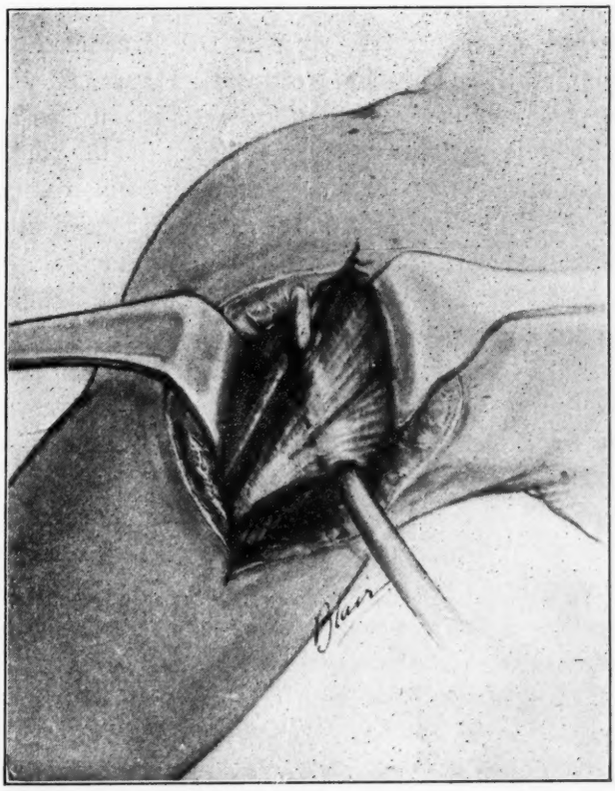

Fig. 8. Showing elevation of pectoralis major tendon. Cephalic vein to outer side.

less harm than the contraction, and results in a more useful arm.

(4) How long should the after-treatment be continued?

At least six months, wearing the splint night and day for at least three months and daytimes for three months more. Exercises, baking and massage at least four times a week.

(5) What treatment before operation is necessary?

Every case should be given the benefit of the doubt, and should have a long course of at least a year of exercises and massage. In very young children it is better to wait until they are at least three years of age before operation.

(6) What can the child do after the operation that it could not do before?

The hand can be supinated, the arm can be outwardly rotated and elevated to above the shoulder level, depending, as said above, on the strength of the deltoid. The hand can be put to the mouth naturally and on top and behind the head to do the hair. At first in some cases—that is, in the first six months or year—there is a persistent inability to adduct or inwardly rotate the arm. This clears up in time and unless the shoulder joint has been opened is no cause of worry. Motion in the shoulder joint is always good in the end, likewise unless the

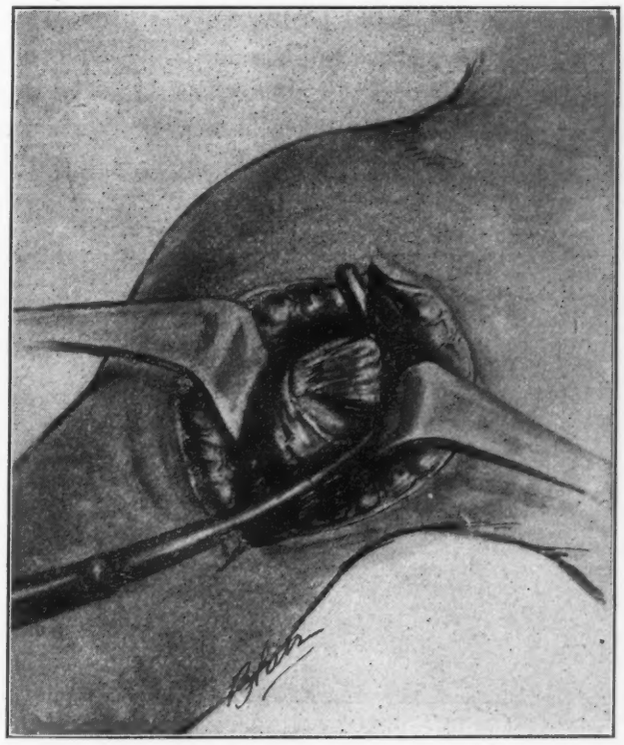

Fig. 9. Pectoralic major divided and retracted. Instrument under tendon of subscapularis. Arm abducted and outwardly rotated.

joint has been opened. A few cases where the joint has been opened have shown a persistent loss of motion in the shoulder and the arm has remained permanently abducted and outwardly rotated, with no motion in adduction. In these cases the free play of the scapula is of great benefit, and allows the use of the arm in a better position, at the expense of stretched rhomboids. The result, however, is not one to be desired, and can be avoided by leaving the capsule intact. Too long fixation following operation, without exercises and massage, will also lead to slow recovery of motion in rotation and adduction.

PROGNOSIS.

The prognosis in all upper-arm type of cases is good, provided the case is watched from the start, and treatment is properly carried out. The patients are practically all able to raise the arm to the shoul-

der level and can use the hand and lower arm well, except for varying degrees of supination. Abduction and outward rotation are rarely regained without division of the contracted muscles, provided they have been allowed to contract.

In the lower-arm type the outlook is not so good, although many of the patients regain use of the upper arm in spite of the persistent paralysis of the lower arm and hand. These cases should all be explored for repair of the plexus as far as possible, but even then very little hope can or should be held out to the parents. The general principle of treatment, however, should be carried out over a long period of time. Much can be done along orthopedic lines for these patients, and they should not be generally neglected as they have been in the past, with the statement that nothing can be done, or that they will get well of themselves.

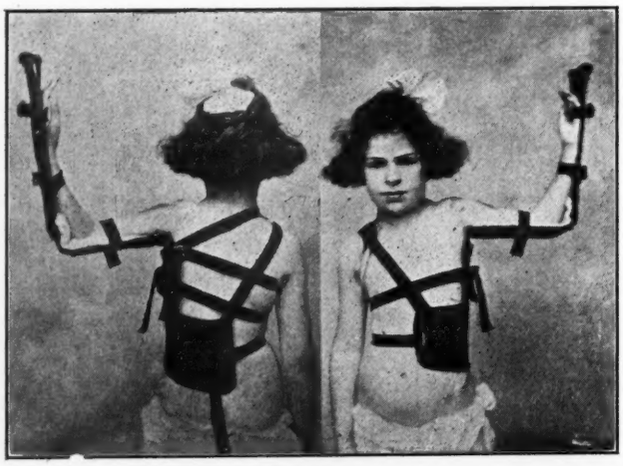

Fig. 10. Front and back view of splint used after operation.

CONCLUSIONS.

Obstetric paralysis is due to stretching or tearing of the cervical roots of the plexus brachialis. It occurs in boys as frequently as in girls. It occurs more often on the right than on the left side.

The upper-arm type is much more frequent than the lower-arm type. Affection of both arms is very infrequent.

It is practically always associated with a difficult labor, in which ether and forceps have been used and force has been applied. Not uncommonly is the baby asphyxiated.

Head presentations show the larger percentage of occurrences of both types of cases.

It may rarely be associated with fracture of the clavicle, but it is not the result of a fractured humerus or a dislocated shoulder joint.

The prognosis for a useful arm is good in the upper-arm type, and bad in the lower-arm type.

FIXATION BY A WOOD SCREW WITHOUT ARTHROTOMY IN CERTAIN FRACTURES OF THE NECK OF FEMUR.

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PHILADELPHIA, PA.

On May 10, 1920, I saw with Dr. John A. Broadfield, a patient he had sent into the Northeastern Hospital with a fracture of the neck of the left femur from a fall about four weeks before. Two days after the injury he was taken to a hospital where he refused to stay longer than two days, during which an *x*-ray picture was taken, after which he was treated at home. As soon as Dr. Broadfield saw him he advised hospital treatment. He was 60 years of age and some years before had sustained an amputation about the middle of the right thigh. He had been earning a good living as a maker of instruments used by artists and draughtsmen and a good functional result from the fracture of the femoral neck was a matter of much importance to him. The delay of four weeks in beginning treatment was a formidable disadvantage in obtaining bony union. I had been impresseed with Delbet's idea of passing a screw through both fragments from the external surface of the great trochanter without arthrotomy, but I had trouble then and have not yet succeeded in finding a satisfactory description or illustration of his method. He depended upon traction for the correction of the displacement of the fragments before introducing the screw and insisted upon the use of a specially devised apparatus for the accurate placing of the screw.

Whitman's abduction method, in my opinion, is decidedly the best for the correction of the displacement and close, accurate approximation of the fractured surfaces. A screw passed through both fragments should prove a valuable help in obtaining bony union after so long a delay in beginning Whitman's treatment. After some thought I conceived the following plan of combining the advantages of the Whitman abduction cast and the screw: On the day following admission to the hospital the patient was etherized, the limb forced into abduction and a cast applied extending from the lower margins of the ribs to and including the foot. A roentgenogram on the following day showed good alignment and approximation of the fragments. A large hole, about six inches from above downward and about eight inches in the long axis of the limb, with the center of the opening about over the great trochanter, was cut in the cast. On May 14th, the patient was etherized and this small exposed skin area prepared for operation

in the following manner: The surgeon gowned, masked and gloved, with a gauze sponge held in a long hemo tatic forceps, first washed the skin with ether. Then with another forceps he pushed the edge of a sterile towel under the upper edge of the cast opening and lapped the towel upward over this margin. Each of the four sides of the opening was prevented from contaminating the skin of the operation area in a similar manner. With the edges of the opening thus draped, the rest of the body was covered with sterile sheets in the usual manner, as shown in figure 3. After painting the skin with tincture of iodin and washing this off with alcohol an incision

Fig. 1. Case 3, before operation.

from 3 to 3½ inches long was made over the most prominent portion of the great trochanter in the long axis of the limb, (see scar in figure 4) through the skin and fascia. Then a sterile towel was clamped to the edge of the wound on each side thus further protecting the wound from infection. The wound was then deepened to the bone which was freed from the overlying tissues well to each side, exposing the anterior and posterior margins of the great trochanter.

The advantage was not recognized in this or the second case of the prominence on the outer surface of the trochanter as a landmark, and the screw was not as well placed as in the other two cases. This landmark is easily seen in the roentgenogram and found on the bone in the operation. By studying the roentgenogram carefully one can determine accurately enough the distance below this landmark at which the screw should be introduced and can decide the angle at which it should be held while driven in to follow approximately the center of the neck in the sagittal plane. I determined the necessary length of the screw by the length of the *x*-ray picture of the femoral neck, but did not allow for the fact that the roentgenographic shadow is larger than the object, because the plate is some distance from the object when it is exposed to the rays. I believe that this largely accounts for the passage of the screw through the head into the acetabulum in this and the

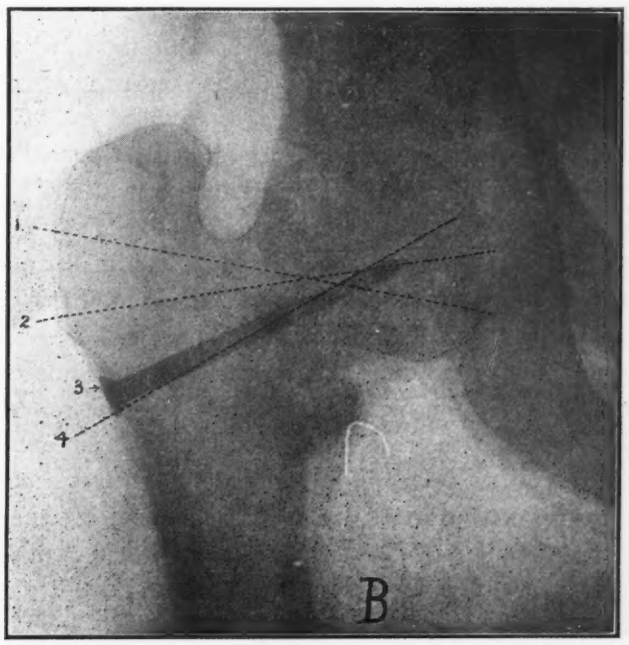

Fig. 2. Case 3, after operation, showing screw penetrating both fragments only slightly below the axis of the neck. An effort was made to show by dotted lines the approximate positions of the screws, a number being given to each to correspond with that of each of the cases here reported. For example, line number 1 shows approximately the position of the screw in case 1, although this screw was placed much nearer the center of the neck than indicated here. The three-quarters of an inch shortening in this case accounts for much of this discrepancy. Note the successive improvement in the judgment of the direction and length of the screw due to the recognition of the important bony landmark and the fallacy of depending on the *x*-ray plate in determining the length of the screw.

second case. Allowance should be made for this by using a screw a half to three-quarters of an inch shorter than the distance from the external surface of the trochanter to the surface of the middle of the head on the *x*-ray plate. We probably have no means of determining whether the screw in any of these cases will leave the neck anteriorly or posteriorly. A suitable *x*-ray exposure for its determination seems impossible. I have not concerned myself much about this phase of the subject since the

cases have been operated upon, because of the excellent results obtained and before the first operation it seemed to me very unlikely that the screw would leave the bone in front or behind. When the foot occupies the vertical position with relation to the leg, i. e., is neither turned inward nor outward, the plane of the neck in the recumbent position will be almost horizontal, but will have a slight forward projection (about 12 degrees according to Whitman). If the screw is introduced about midway between the anterior and posterior borders of the great trochanter with a slight inclination forward there will be very little likelihood of its emerging from the bone anteriorly or posteriorly. But, for the sake of argument, let us suppose that it did so emerge, what harm could it do? If it had a good hold of the inner or small fragment I should have little concern. It can be removed easily later if it gives trouble.

After selecting the point for the introduction of the screw and placing it in what I considered the proper angle from a careful study of the *x*-ray picture, it was driven in about halfway by a mallet and for the remaining distance by a large screw driver. In my first case I drilled a preliminary hole for the screw, but later found that it was easy and satisfactory to drive the first half of it through the cancellous tissue of the trochanter. The last half was forced in by a screw driver in order that it might get a better grip on the inner fragment and make a tighter approximation of the two fragments. The wound was then wiped out with a little dichloramine-T and closed completely. A dressing was applied and the cast and its opening reinforced by several plaster-of-Paris bandages. In not one of the four cases did the slightest sign of infection develop.

Phocas in one case had the help of Cara, an assistant of Delbet, in applying the Delbet apparatus for the accurate placing of the screw and of this case Phocas said that the *x*-rays afterwards showed the screw a little too low, not passing in the axis of the head, and extending through the head and encroaching upon the acetabular cavity. Delbet, in discussing this case, did not see any disadvantage in the deviation of the screw nor did he criticise its encroachment on the acetabulum. According to my own experience this is a matter of minor importance and probably interferes little or not at all with the permanent value of the operation.

CASE I. This case has already been described up to the completion of the operation. There was no disturbance of the wound afterward. He was discharged from the hospital two weeks after operation to lie in bed at home under the care of Dr. Broadfield, who removed the cast at the end of nine weeks. Gradually he became accustomed to his crutches again and about five weeks after the removal of the cast he began to follow his usual occupation which required frequent rising from the sitting position and walking about the room on crutches. He was soon able to do as much work as before the fracture and has done it ever since. On July 13, 1921, under anesthesia with nitrous oxid and a little ether the screw was removed and after two days he left the hospital. Before the screw was removed he could flex the hip to about a right angle, but beyond this he would develop pain. At this time roentgenograms showed that the end of the screw had worn away a portion of the bone in the acetabulum by its movements. There is no eversion of the foot and he can turn the foot inward and outward almost to the normal degree. He has normal use of the limb except for the slight pain on forced movement due to the projection of the screw into the acetabulum.

CASE II. Woman, 65 years old. Thin, pale and weak. Fell down stairs about July 27, 1920, and fractured neck of left femur. Treated by Buck's extension and sand bags at home until admitted to the University Hospital, October 27, 1920 (13 weeks after the fracture occurred). Whitman abduction cast applied November 2nd. Screw introduced November 17th, and patient sent home to lie abed in cast until December 20th (33 days after the screw was introduced). Returned to hospital January 27, 1921, to have the cast removed (10 weeks after operation). Roentgenogram seemed to show bony union. Sent home again February 2, 1921. Remained in bed at home without cast about two months before attempting to get out of bed on account of weakness and timidity. Then increased her stay out of bed gradually for about a month when she began to use crutches and then required about two months more to come downstairs. At the present time, July 14, 1921, she flexes the hip joint about 70° and the knee nearly to right angle. Complains of no pain in knee or hip. Tried first time to walk without crutches and took about a dozen steps timidly but without pain. Holds foot of affected side in about same degree of eversion as normal foot and can turn foot

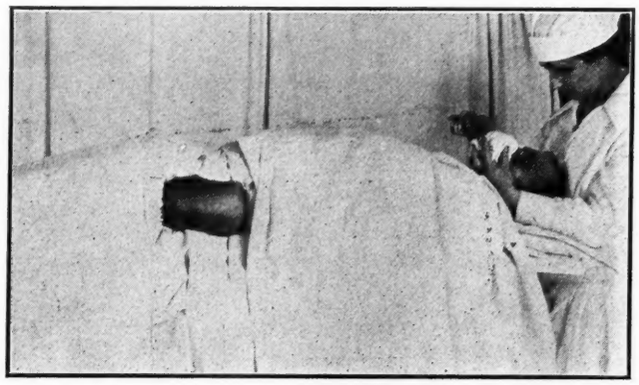

Fig. 3. The hole cut in the cast is here shown draped and ready for the making of the incision and introduction of the screw.

into inversion well past the midposition. Frequently goes about with one crutch.

CASE III. Russian immigrant, 42 years old. Strong and healthy. About August 15, 1920, a horse running away, he was thrown from a farm wagon, injuring his left hip. About three weeks later he was taken to a hospital in a neighboring town where an *x*-ray picture was taken and he was told that there was no fracture. He seems to have been put up in a Buck's extension indicating a suspicion of fracture, and remained therein some weeks. He was admitted to the University Hospital, December 4, 1920, with a

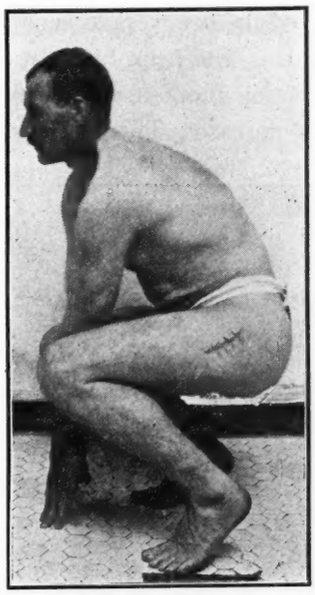

Fig. 4. Case 3 is here shown demonstrating his ability to flex his left hip and knee joints while sustaining his weight upon his feet. The right or normal limb is capable of still more flexion in both joints. Note the scar of the incision and the absence of eversion in the left foot, which was characteristic of all four cases.

considerable indurated swelling in the region of the left hip which, in view of the negative *x*-ray report, was suspected of being a sarcoma. An *x*-ray picture taken at the University Hospital showed clearly a fracture of the femoral neck (see figure 1), and he was transferred to the fracture service. In view of the long period that had elapsed since the accident it was considered advisable to introduce the screw. The abduction cast was applied December 12th and the screw introduced December 21st. The cast was removed February 28, 1921, 9½ weeks after the screw was introduced. Five days later he was walking with crutches and could take nearly his whole weight on the foot of the injured side. Discharged March 9, 1921. Readmitted to the hospital July 5, 1921. He walks easily and quickly without pain, but with a slight limp due chiefly to some limitation of movement at the hip and knee joints although he can force these movements almost to the normal (see figure 3).

CASE IV. Man, 33 years old, oyster opener. On February 26, 1921, while delirious from pneumonia jumped from a second story window landing on a cement pavement below. His chief injury was a comminuted intertrochanteric fracture of the neck of the femur. Because of his lung condition it was impossible to correct the considerable deformity since he could not take a general anesthetic until March 30th, (32 days after occurrence of the fracture) when the Whitman abduction cast was applied. The screw was introduced April 11th, and the cast reinforced at the hip. He was allowed out of bed in a wheel chair in the reclining position April 26th. The original cast was removed and a new one allowing the limb to be adducted as far as possible applied on May 9th. Two days later (30 days after introduction of the screw) he began to walk on crutches. May 13th, he first stood on both feet without the crutches or other support, with the cast on, and then took his whole weight on the foot of the injured side without experiencing any pain at the hip. He was then advised to walk as much as possible without crutches. Cast removed entirely eight weeks after screw was introduced. On July 15th he reported that he had used a cane only two days after the removal of the cast and had been going about ever since without support. He walks easily without pain but with some limp. His chief trouble comes from stiffness at the knee which he can flex only about 10°, He can flex the hip to about a right angle. Could have returned to work as an oyster opener a month ago but it is out of season and he can get no other suitable work.

CONCLUSIONS.

1. The screw as here employed is beneficial in cases too long deprived of the advantages of the Whitman correction of displacement, close approximation, and fixation of the fragments.

2. Its introduction by means of the technic described is safe and sufficiently accurate for the purpose intended.

3. The chances of infection are almost nil.

4. The patient, if young enough, may be permitted to get about on crutches with the cast on at the end of 4 or 5 weeks following the introduction of the screw. This will prevent any displacement of the fragments and the weight-bearing will favor the more rapid and certain development of bony union.

5. More time is necessary for final judgment in any of these cases but enough good has been accomplished in all to warrant further trial of this method of treatment in selected cases.

When operating for osteomyelitis of the fibula in children, it is advisable at once to perform subperiosteal resection of the affected length of the shaft.

That a bone appears normal by fluoroscopy does not gainsay a fracture. An *x*-ray plate may show it when the fluoroscope fails to do so.

OPERATIVE TREATMENT (ARTHRODESIS) FOR OSTEO-ARTHRITIS OF THE HIP.

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Osteoarthritis of the hip is a chronic condition which attacks young and middle-aged as well as the aged. It is characterized clinically by a slow and gradual onset, absence of fever, local pain, muscular spasm and wasting, stiffness, disability and deformity, never presenting any tendency to suppuration. It may or may not be associated with similar conditions in other joints. It may be implanted upon an old healed destructive arthritis such as tuberculosis.

The etiology of this affection is still obscure. It has been ascribed to exposure, traumatism and some chronic infection in which injury certainly plays some part. I am convinced from a large experience and careful study of many cases and the statistics of others, that old age plays a minor part only in its etiology.

At the International Congress, Budapest, 1909, I reported in detail 14 cases successfully operated upon; of these six were thirty years old or younger.

Whether the initial lesion of arthritis deformans is in the synovial membrane, the cartilage, or the bone, is a matter still in dispute. Schuller has described a bacillus found in these joints, with which he has been able to produce similar lesions in animals. His results have not been confirmed. Dor has injected attenuated cultures of the staphylococcus into joints and produced lesions quite similar.

Early in this process the synovial fluid is increased, later it becomes diminished, and may almost disappear. Changes in the cartilage occur early, cells multiply and the hyaline substance degenerates. The hyaline cartilage takes on a yellowish appearance and the articular surfaces become thinned in the center, finally disappearing entirely. The head of the bone thus laid bare becomes smooth, polished and eburnated. The affection is characterized by destruction and absorption. "Marginal ecchondroses or osteophytes appear and may become so large as to perforate the synovial membrane and become pedunculated or even detached, and appear as loose bodies in the joint. The head of the bone may become locked in the grasp of these bony outgrowths and motion be greatly interfered with, so much so that much wearing away of the head does not take place. On the other hand, if motion continues, the head may become flattened and in some cases almost entirely worn away, thus exposing the Haversian canals and presenting a worm-eaten appearance".

"The acetabulum is deepened both by the wearing away of its floor and the ossification of the cotyloid ligament. In any event the motions of the hip are much limited and tend toward that of a cylindrical joint, on account of its anatomic changes".

The head wears away more and more and the marginal outgrowths progress toward the trochanter. In addition to this, the neck hypertrophies and may bend, thus forming more nearly a right angle with the shaft than normal. This event, as well as the wearing away of the acetabulum and the flattening of the head, results in an elevation of the trochanter above Nélaton's line and a consequent shortening of the leg. This actual shortening varies a good deal and averages about one-half of an inch. Further than this, a very important feature is the consequent practical shortening and its resulting disability, resulting from the deformity of adduction and flexion.

Fig. 1. Photograph of a brace which had been worn for 9 months by case G. D. It weighed 12 1-2 pounds and the patient claimed that the discomfort from it was as bad as the disease.

From an *x*-ray standpoint this condition differs greatly from that of tuberculosis or any other type of arthritis. Contrasted with the rarefaction and disintegration of tuberculous arthritis, this condition shows great increase of density of the elements of the joint from eburnation and the accumulation of osteophytes around the superior, and usually also

the inferior, margin of the joint, associated with varying degrees of flattening of the head.

The onset is insidious, with pain in and about the joint, often shooting down the course of the sciatic nerve or in many instances to the region of the knee. Motions of the joint beyond a certain arc are painful. External rotation, abduction and hyperextension are particularly painful and later in the course of the disease are much limited. Muscular atrophy comes on early, and the buttock of the affected side becomes flaccid and flattened. The arc of motion gradually diminishes until finally the joint may become entirely stiff, from a functional standpoint.

The severity of pain and the amount of effusion in the joint varies within wide limits. A peculiar crepitation produced by the rubbing of the roughened synovial membrane and osteophytes may be present when the leg is manipulated. Motion may be almost or entirely lost either from muscular spasm, grasp of the surrounding osteophytes, disappearance of the synovial membrane, or flattening of the head of the bone. A very important diagnostic point is the fact that if motion exists in the advanced cases it will be practically in one plane, that of flexion. The earliest limitation of motion is in abduction and rotation. This is explained mechanically, as above, by changes that make the joint, instead of spherical, practically a cylindrical one. Flexion may be moderately limited, whereas abduction and rotation may be nearly absent. No other condition, with slight bony shortening, produces this symptom-complex.

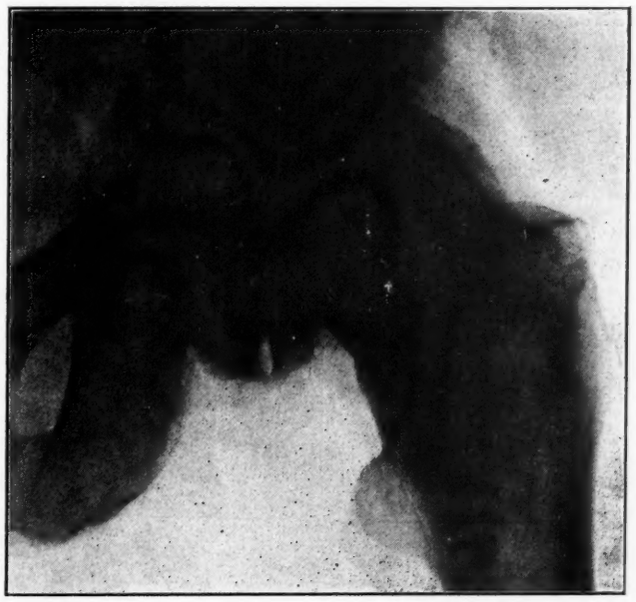

Fig. 2. Roentgenogram of the affected hip of G. D. before operation.

Summary of Clinical Features: Briefly, the clinical manifestations of osteo-arthritis (arthritis deformans) of the hip are:—

"(a) Insidious onset.

"(b) Symptoms manifested only during locomotion.

"(c) Motions of the hip change from those of a ball-and-socket joint to those of a hinge-joint.

"(d) The axis on movement of this hinge-joint in flexion is always obliquely outward, and varies in its obliquity to the antero-posterior plane of the pelvis in different cases.

"(e) Muscle spasm, on passive motion, may be entirely absent.

"(f) Marked contrast of the *x*-ray appearance to other conditions which simulate it clinically.

"(g) The frequency of trauma as an etiological factor". (Albee, Orthopedic and Reconstruction Surgery.)

Partial temporary relief may be secured by rigid regulation of the patient's habits and occupation, especially by keeping him off the limb. Local massage, friction and manipulation of the joint in abduction and extension with or without an anesthetic may halt the progress of symptoms. A focus of infection, of which the hip condition may be secondary, should always be carefully sought for and, if found, should be eradicated, if possible. Vaccines made therefrom and systematically administered, rest in bed with traction apparatus, if necessary, will do much toward relieving discomfort temporarily. The stiffness in the early stages is due to muscular spasm and not to ankylosis, and is diminished, therefore, by any measure that protects the joint. Traction is indicated when passive manipulation is painful and restricted by muscular spasm. The patient should lie in bed with weight and pulley arranged as for ordinary hip disease. The weight, approximately ten pounds, should pull in the normal direction of the leg unless pain is caused or excessive malposition of the leg exists. In either event the traction should be in the line of the deformity.

It is rare that much can be accomplished by braces. It is the usual conclusion of the patient that the treatment by braces is as bad as or worse than the disease (see figure 1). This is due to the unfortunate difficulty of efficiently bracing the adult hip joint without undue discomfort to the patient.

Where the condition is at all advanced with marked anatomical and pathological changes, such as wearing away of the top of the femoral head and acetabulum, osteophytes and the associated flexion and adduction deformity, satisfactory results can

rarely be obtained, short of the operative treatment about to be described.

Complete resection of the head and neck as practiced by Hoffa is not to be recommended. It is rarely possible in the most carefully selected cases to get relief from forcible manipulative procedures under ether. Baer, in 1913, recommended arthroplasty to preserve mobility in certain cases of this type. This consisted of resecting a considerable portion of the femoral head, including the osteophytes. In most cases he did not place any material, such as prepared pig's bladder, between the femoral head and acetabulum. Since this report I have carefully selected and operated upon four cases by this method. The results in all of these cases have not been as satisfactory as those obtained by the arthrodesis operation in the single hip involvement. Pain in a varying degree has persisted. At the same time I have successfully been employing mobilizing arthroplastic operation for other hip conditions with ankylosis.

There is hardly any operation that gives a larger percentage of very grateful and satisfied patients than the arthrodesis, devised by me and first reported in the *Journal of the A. M. A.*, June, 1908.

To date, 128 cases have been operated upon with very gratifying results.

ILLUSTRATIVE CASE.

G. D., a policeman, 52 years of age, and weighing 220 pounds; consulted me September 1, 1919, and gave the following history: For four years he had had pain in the left thigh and knee; he had noticed also that the limb had become short and stiff at the hip. At first he experienced pain only when walking. Later the pain became much more severe, both by day and by night. He received much treatment of a large variety. Nine months before he had an extension brace made (see figure 1) which he found gave him no relief. This brace weighed 12½ pounds and extended from the foot to above the costal margin on his trunk. He stated that this brace had added to his discomfort but had given no relief. Many patients suffering from the same condition have made the same statement to me. Figure 2 is an *x*-ray picture of this case. He was operated upon at the New York Post-Graduate Hospital, September 13, 1919.

With the patient in the dorsal position on the Albee fracture-orthopedic table, the feet were covered generously with plaster cotton and bound to the traction foot-pieces with 4-inch muslin bandages. The hip-joint was reached by the Sprengel or Smith-Pedersen approach. The skin incision was made along the crest of the ilium from a distance five inches posterior to the anterior spine forward to the anterior superior spine itself, and then straight down for a distance of 4 inches. The fascia lata was cut parallel with the crest of the ilium and about half an inch below it, thus furnishing a means of suturing the fascia to the crest of the ilium when closing the wound. The gluteus minimus and medius and tensor vaginae femoris muscles were then separated subperiosteally from the side of the ilium by means of a broad osteotome, and carried downward to the superior surface of the hip-joint. The proposed triangular skin and muscle flap was then completed by blunt dissection down from the anterior superior spine and just outside of the sartorius muscle. This gives the best exposure of the hip-joint.

The joint capsule was then laid open by a T-shaped incision, the top of the T being parallel to and just below the rim of the acetabulum. By attempting to rotate the femur in and out, a close inspection of the joint confirmed the *x*-ray findings,

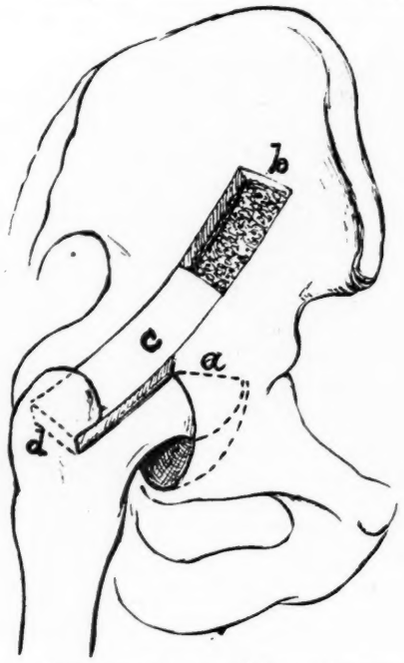

Fig. 3. A diagrammatic drawing to illustrate the author's latest technic in the operative treatment of osteo-arthritis, selected cases of tuberculosis and flail paralytic condition of the hip.

namely, that there was a rim of osteophytes extending from the edge of the acetabulum and also from the outer rim of the femoral head. The synovial membrane and hyaline cartilage were largely absent from the top of the femoral head, in fact, this portion of the head had the well-known worm-eaten appearance caused by the bone being actually worn away after the loss of the cartilage. The bone was also polished and glittered like marble.

With a broad chisel and a mallet a large portion of the osteophytes on the rim of the acetabulum was removed; and with the same instruments about one-fifth of the top of the head of the femur was removed through a plane sloping inward and upward, and, also with the same instruments, the top of the acetabulum was transformed into a flat surface (figure 3, *a*). While the femur was being rotated strongly inward and outward, all accessible cartilage was removed from the remaining portion

of the femoral head. This allowed the freshened plane surfaces of the femoral head and the acetabulum to come nearer together, though not in close proximity.

The table was then adjusted so as to bring the foot straight up, and the limb was abducted at the hip about 10° and flexed about 10°. The digital fossa on the inside of the trochanter was then deepened by means of a narrow osteotome and mallet, thus making a groove about ½ inch wide and about ¾ inch deep in a plane parallel with the outer surface of the ilium just above the acetabulum (figure 3, *d*).

With the point of a scalpel, a large graft was then outlined in the periosteum on the outer surface of the ilium, 3½ inches long by 2 inches wide, its lower end including the superior rim of the acetabulum. With the Albee motor saw the graft was then cut

Fig. 4. Roentgenogram of the hip of G. D. after operation, showing complete bony consolidation of the graft, head of femur and acetabulum. The arrows indicate the sliding inlay graft brought down from the outer table of the ilium just above the hip joint and inlaid into both the ilium at and above the acetabulum and the neck and trochanter of the femur.

through the outer cortical table of the ilium according to the pattern outlined. It was then removed from its bed with a broad thin osteotome.

If care is not exercised in this work the inner cortical table of the ilium will be damaged or a portion of it removed.

The large rectangular graft thus obtained was turned end to end, and what was the upper end was thrust firmly into the groove in the upper end of the femur, the other end being placed in the lower end of the gutter formed by removing the graft, as shown in the diagram (figure 3, *c*).

In a way, this is another application of my inlay graft which I have so frequently used in ununited fracture of the long bones.

Attention should be called to the change in the technic of this operation from that originally practiced by me. In the first cases, done some 15 years ago, great care was taken to remove from the wound all loose fragments of bone. In fact a special fountain douche apparatus was devised to wash out all bone fragments from the hip. Now a large graft is used and favorable fragments of the femoral head are put back again to serve as additional foci of bone growth. This illustrates the modern conception of bone growth and is far-reaching in its application and results.

The wound was then closed with a continuous suture of chromicized catgut in the fascia, and a continuous suture of No. 1 plain catgut in the skin. The approximation of the affected muscles against the side of the ilium thus secured was very gratifying.

It may be noted that this approach does very little damage to the muscles or their enervation or other soft parts of the hip, and its introduction constitutes almost an epoch-making event in the plastic surgery of the hip-joint. I use this approach for all plastic operations upon the hip-joint, reserving the anterior incision for approaches to the neck of the femur only.

The suture holes in the skin were then puddled with 3½ per cent tincture of iodin, extensive dressings of gauze and absorbent cotton were placed over the incision, and a long plaster-of-Paris spica was applied from the base of the toes to 2 inches below the costal margin on the right side and 3 inches above the costal margin on the left. This splint was worn for a period of eight weeks, after which an *x*-ray plate indicated firm union of hip-surfaces and graft. The patient was allowed up and about on crutches, bearing some weight on the foot.

The subsequent convalescence of this patient has been most satisfactory, in that all pain has ceased, and he takes a rather paradoxical view of the result of the operation, for he says he has more motion of the hip now than before the operation.

This attitude of the patient has been noted in a number of other cases, and is accounted for by the fact that the absence of pain overcomes the muscle spasm at the lumbar spine, knee, etc., to such a degree that compensatory action of the surrounding joints is surprisingly restored. Although the operation destroys the motion of the particular joint, nevertheless, from the point of view of the patient, the results are brilliant. Figure 4 is a roentgenogram of this case six months after his operation. The arrows point to the inlay graft slid down from the outer table of the ilium.

ARTHRODESIS FOR LOSS OF HEAD AND NECK OF FEMUR. A CASE REPORT.*

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Auto-transplantation of the head and part of the shaft of the fibula has been successfully performed for loss of the head and neck of the femur. Its success, however, is not accomplished without a great deal of discomfort to the patient, such as treatment extending over a period of from one and one-half to two years, long confinement in bed, inability of the patient to use the leg as a weight-bearing member for at least a year and at times failure due to absorption of the graft.

Fig. 1. Fracture with absorption of the neck and greater portion of the head of the femur.

On account of these inconveniences, I concluded to try another procedure for the relief of this condition. This consisted in the removal of the top of the great trochanter, the acetabulum and the outer compact table of the os ilii until cancellous bone was reached. This operation and patient I present here for consideration.

Miss L. C., aged 26, a patient of Dr. Paul, was referred to me May 20, 1919.

She had had the usual diseases of childhood, but otherwise was well until September, 1916, at which time she was operated upon for appendicitis and uterine trouble. Her recovery from this operation was uneventful and she remained in good health for a period of nine months, but at the end of this time she became very nervous. In September, 1917, she fell from the second story window, fracturing the neck of the left femur, and was treated for eight weeks by the use of Buck's extension. She was then up and about on crutches and later used a cane until I saw her in May, 1919.

Examination: The patient was well nourished and weighed about 135 pounds. Pupils reacted normally to both light and accommodation. The mouth and teeth were in exceptionally good condition. The heart and lungs were normal. The reflexes were normal. The abdomen showed a tranverse scar in the lower part due to previous operation. There were no herniae present. The left leg was three and one-half inches shorter than the right with the patient in the recumbent position. Pressure made against her foot increased the shortening two inches. The Wassermann reaction was negative. *X*-ray examination showed a total loss of the neck and almost complete loss of the head of the left femur.

Fig. 2. Thigh at right angles to body in plaster cast.

Fig. 3. Condition when patient left hospital, August, 1919.

Operation: May 26, 1919, under gas anesthesia. A U-shaped incision was made over the left great trochanter and the skin and fascia turned upward. A chain saw was passed around the upper end of the great trochanter and this portion of the trochanter sawed off. By this procedure, the obturator internus and pyriformis muscles attached to this bone were reflected and we were brought immediately down

*Read before the Buffalo Academy of Medicine, March, 1921.

upon the false joint which had been produced by absorption of the bone. It was found that the neck of the femur was entirely gone and only a small portion of the head remained. This was so soft that it

Fig. 4. Eighteen months after operation. Thigh in abduction with tilting of pelvis.

was considered to be of no value—any operation done with the object of connecting the remaining portion of the head with the trochanter would have proved a failure. I then decided upon the following

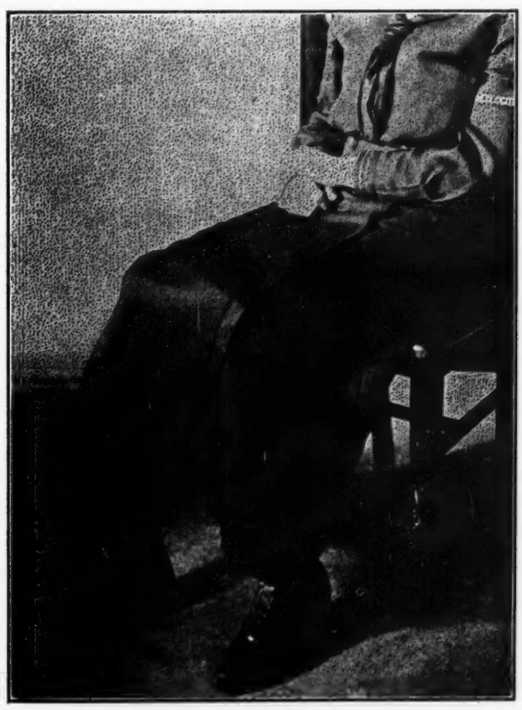

Fig. 5. Sitting posture.

operation as the one most advisable:

The head and cartilaginous tissue were removed from the acetabulum and the upper half of the acetabulum was gouged out until the cancellous bone of the ilium was reached. By this procedure, I had secured a shelf against which the sawed end of the trochanter could rest and act as a support to the body. I then placed the end of the trochanter into the socket, after freshening the outer surface of the trochanter so that I could replace the part that had been removed earlier in the operation. This piece of bone was sutured in place with chromicized catgut. At this point I also made sure that there was ample room for the thigh to move anteriorly and posteriorly so that the patient could walk about and also sit comfortably on a chair. The thigh was placed at right angles to the body, the wound closed and a body cast of plaster was applied. The cast was removed at the end of six weeks and during the next seven days the extremity was gradually brought parallel with the right. At the end of nine weeks the patient was out of bed and about the room on crutches. She left the hospital August 11, 1919. At the end of one year she walks without crutches or cane and has a very useful extremity with 1½ inch shortening. The accompanying cuts will serve to illustrate her present condition.

This operation, I believe, has the following advantages:

1. It is more likely than others to be successful.
2. It does not confine the patient to bed a great length of time.
3. The patient has a useful extremity.

I am sure that if extreme abduction as described by Whitman is used in this type of fracture, absorption will rarely, if ever, take place.

Testing Nerve Function.

When testing pin-prick the pressure of the pin should always be accompanied by that of the pad of the observer's finger; otherwise the patient will find it hard to distinguish between the pressure of the pin and its painful stimulus, with much consequent waste of time. The pressure sensation evoked by the pin is part of the deep pressure sense, and dependent on different fibers from those responsible for the epicritic pain sense. In our experience the deep pressure sense returns sooner, and is lost less often, than the epicritic.

In testing Tinel's sign, care must be taken not to be misled by tingling from an adjacent nerve, as in so many regions two or more have an identical course, e. g., the ulnar and internal cutaneous in the upper three-fourths of the arm. By asking the patient to mark out the peripheral distribution of the tingling, this error is avoided.

Muscle tenderness is sometimes hard to tell from nerve tenderness where the nerve runs through the muscles it supplies, as the ulnar does in the palm of the hand.—M. Forrester-Brown in *The British Journal of Surgery.*

THE TREATMENT OF FEMUR FRACTURES

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From a purely statistical viewpoint, how much more serious than many other surgical conditions is the fractured femur! A simple appendicectomy wound heals in seven to ten days, that of a suppurative case in six to ten weeks; a cholecystectomy case is cured in six weeks or less, and, if drained, in ten to twelve weeks at the utmost; intestinal anastomosis, or gastro-enteric-anastomosis are restored to function in three to six weeks, while a well-treated, properly healed femur fracture, as a rule, takes six months before the resumption of the artisan's occupation can be undertaken.

As Sir Robert Jones ably states, "fractured femurs were the great calamity of the war", so also are they the great calamity and problem of the industrial warfare for sustenance.

Fractures of the femur can be classified in two general ways:

1. According to the extent of the lesion, as,
   (a) Simple, or
   (b) Compound.
2. Anatomically, as,
   (a) Of the upper third;
   (b) Of the middle third;
   (c) Of the lower third;

and their treatment will vary accordingly.

Certain essential objectives must be kept in view in the treatment of all of them. Briefly stated, they are:

1. The attainment of complete reduction, if possible.
2. Firm bony union.
3. Keeping the correct relations of the anterior planes of the upper and lower fragments.
4. The prevention of shortening (a good result, according to the report of the Fracture Committee of the American Surgical Association, should show no shortening of over one-eighth to one inch).
5. Prevention of lameness, due to knee stiffness or shortening.
6. The restoration of the patient to efficiency as a workman, in the minimum time commensurate with proper union. This can seldom be attained in less than six months.

As basic principles of treatment, to gain these results, the following two rules should be axiomatic:

1. The distal fragment is the mobile one and must, by one method or the other, be brought into axial relationship with the proximal fragment and maintained there.
2. The limb must be put into the posture of neutral muscle pull. There will then be less tendency to displacement.

All traction or fixation should at all times be carried out with these two basic factors in view.

Two other fundamental principles that are of tremendous importance should be recognized.

1. Frequent *x*-ray examination should be the rule. Fragments slip, traction is not sufficient; malformation is the result. The *x*-rays will readily demonstrate such a defect.
2. Whenever a fracture is put up in traction, such as obtained by a Thomas splint, daily inspection of the conditions present should be made. The mere application of a traction apparatus is only the beginning of the treatment. The painstaking subsequent after-care of these fractures is the only sure way of obtaining proper results. To allow such an apparatus to go without inspection for a month or more, as I have frequently witnessed, will, in nearly every instance, eventuate in malposition or malunion.

At all times the surgeon should familiarize himself with the anatomy of the region involved in the fracture, and the various forces acting upon the fragment, and be ready to adapt new principles or variations of the old to bring about results. These conditions are best met by careful *x*-ray study, and it is for this reason that I shall not here enter into a discussion of the processes involved in the so-called typical fractures, nor shall I attempt to exhaust the various methods that may be employed and discuss their relative value. Certain definite facts have impressed themselves as common to the treatment of each region, and it is from this viewpoint that the treatment of the individual fractures will be considered. This will explain certain apparent omissions of methods that have been effectual with other workers.

First-Aid Treatment.

The treatment should be begun as soon as possible after the injury. Proper emergency care means the prevention of deformity and bleeding into the muscles and fascial planes, with subsequent hematoma, myositis, or nerve injury. This is best effected by the early use of the Thomas splint, that is, prior to any attempt at transportation of the injured individual.

The splint should be applied over the clothing and traction begun immediately. This can be effected by one of two methods:

(a) By splitting laterally through the uppers of the shoes at their junction with the sole, and then passing a bar of metal or wood transversely under the arch of the foot, through the shoe. This bar should rest upon the side pieces of the Thomas splint; to it, on each side, should be attached extension strips running to the V-shaped end of the Thomas splint and tied there. A posterior splint of some sort should then be applied and the whole limb bandaged from the ankle to the groin. The splint should be suspended so that the heel does not rest upon the stretcher.

(b) A second, but inferior, method of obtaining extension is by the use of a rope tied in a clove-hitch over the foot, with the Spanish windlass form of traction.

A number of special emergency extension devices have been invented, but, as a rule, these are not available at the time of fracture. We have found an Esmarch's tourniquet to be satisfactory. A piece of inner tubing from an auto tire will answer the purpose.

Hospitalization.

All cases of fracture should be placed in hospitals for treatment, as their care requires frequent examinations, adjustments, and Roentgen pictures, all of which cannot well be obtained at home.

Immediate X-Ray Examination.

An *x*-ray examination should be made immediately in every case, both before and after the splint is applied. This will demonstrate the immediate pathology and aid in obtaining proper alignment of the fractured ends.

FRACTURES OF THE UPPER THIRD OF THE FEMUR.

Fractures of the Neck.

The Intertrochanteric Type. These types of fractures can readily be developed into those of (a) the aged, or asthenic variety, and, (b), the adult or sthenic variety. In industrial surgery, the former types are rare and we shall not discuss them here. As a whole, they are unsatisfactory cases to treat, and might well be a subject for study by themselves. The latter type can be properly managed by either the Whitman abduction method or the combination of the Cotton with the Whitman method. If impacted and not in proper position, (remembering that we are dealing with the industrial type of case) the impaction should be broken up. This is best effected under anesthesia, the patient being placed upon a Hawley or Albee table.

Stated briefly, the various steps in the Whitman method are the following:

1. Traction and extreme abduction of the leg.

2. Rotation of the leg inward, bringing the trochanter forward.

3. The elevation of the trochanter by pressure from behind.

4. The application of a plaster spica extending from the toes to the nipple line, the leg being held slightly inverted and strongly abducted. A "dinner pad" should be put over the stomach, and smaller pads, to prevent pressure, should be placed over the anterior-superior spines, the sacro-iliac joints, the trochanters, the femoral condyles, and the malleoli.

The Cotton method simply adds to this the impaction of the lower fragment in proper position into the upper.

It might be well to mention here that we have found the Thomas splint is ineffectual in this type of case, in so far as it is impossible to maintain proper abduction. As a rule, the patient slips over in bed and lines the pelvis up with the abducted leg, entirely vitiating the attempt at abduction. This difficulty can be overcome by using two Thomas splints, one on each leg, thus preventing pelvic tilting, or by the use of the Crile modification of the splint, consisting of the addition of a pelvic band which prevents pelvic movement. This method is utilized in Canada and Great Britain, but this splint is difficult of obtainment in this country. The Whitman method gives by far the best results, however, and as it is so simple of application, is probably the best method of treatment of this type of case.

Fractures of the Greater Trochanter.

These are best treated by abduction and flexion of the thigh. If the fragments are widely separated, open operation should be instituted and the fragments held in place by some form of bone fixation, the autogenous bone peg being most effective and scientific.

Fractures of the Lesser Trochanter.

These should be treated in sharp flexion with a mild degree of adduction; probably the best way of attaining this position is by having the patient sit up in bed. In this way the traction of the psoas muscle is released and the fragments allowed to approximate. No special form of splint is required.

FRACTURES OF THE SHAFT.

The treatment of this type of fracture can be summed up in the proper use of the Thomas splint. All other forms of fixation, open operation, plating or wiring, can be relegated into the discard heap of surgical procedure, for if properly employed, the Thomas splint brings almost invariably good results. However, certain definite points must always be borne in mind, else failure may ensue:

1. A large-ringed Thomas splint should be utilized.

2. The ring must be held firmly below the tuberosity of the ischium. If this is not done, pressure sores result, as well as tilting of the pelvis. Besides this, the ring is not held clear of the anus and rectal function is interfered with. To maintain the proper position of the ring, a suspension cord is run upward to a pulley on the Balkan frame, and passes backward through a second pulley to behind the head of the bed. To it are attached weights (seven to ten pounds, as a rule, are adequate). Thus pull holds the ring snugly against the ischial tuberosity, even when the patient is moved or rises in bed.

3. Whenever possible, a knee flexion splint should be employed. This consists of the lower half of the Thomas splint attached to the sides of the main splint by a hinged attachment allowing of movement up and down, and giving free extension and flexion at the knee. A suspension rope passes from the end of the splint upward to a series of pulleys. The proximal end of the rope is attached to the ring of the Thomas splint. The patient can then, by pulling on the suspension rope, move the knee up and down at will. The maintenance of this free mobility at the knee is of extreme importance, as one of the commonest permanent deformities ensuing from fracture of the femur is stiffness at this joint. It should always be guarded against by massage and free movement.

4. The foot should be maintained at right angles to the limb. This position can be obtained by glueing the lower half of the sock to the plantar surface of the foot, or by means of a broad adhesive strip similarly applied. From this a suspension rope is run to an overhead pulley, to which is attached a light weight (two to three pounds are adequate.) Never should the sock or the adhesive plaster be permitted to pull from the tendo achillis, as pressure sores are sure to result.

5. Suspension of the leg is effected by means of transverse straps of bandage or flannel, four inches wide, fastened securely to the sides of the Thomas splint by paper clips. The first strap, known as the "master strap," should be placed directly under the site of the fracture and should never be removed. It should be just tense enough to allow the soft parts to ride at a level with the side bars of the splint. The remaining suspension straps should be adjusted snugly to the limb. If properly applied, as a rule, backward bowing of the femur is prevented.

6. Lateral bowing, or displacement of the fragments, is prevented by means of pressure pads attached to the sides of the Thomas splint, made adjustable by set screws, which allow the application of the pressure wherever desired. The discs of these pressure pads should be made of wood, so as to allow the taking of *x*-ray pictures without their removal. In the case of marked anterior or posterior bowing, similar pads can be adjusted to the Thomas splint by means of metal arches attached to the side bars of the splint, to which the pressure discs are fastened, and pressure from either the front or behind thus obtained.

7. Traction. This is of two types, either skeletal or indirect. By skeletal traction is meant traction directly from the displaced distal fragment of bone. Numerous methods have been advocated, but all resolve themselves into modifications of the Steinmann nail traction or the ice-tong or caliper traction. Best results are probably obtained by some form of the ice-tong variety of traction. Certain specific precautions should be observed with this form of treatment.

(a) Strict asepsis must be observed.

(b) The synovial membranes and sacks about the knee must be avoided.

(c) The thinner parts of the condyle of the femur must be avoided by fixing the points of the caliper at the denser part of the bone at the level of the adductor tubercle.

(d) The tongs should be provided with guards to prevent their penetration of the bone and the meeting of their points.

Indirect traction is the type obtained by the application of adhesive bands or by means of cloth strips fastened to the leg with some form of glue,—Sinclair's, Heussner's, or the one preferred by the British, consisting of five per cent. celluloid dissolved in commercial acetone (the latter can be readily prepared from old *x*-ray films from which the emulsion has been removed.) Its sole objection is that it frequently causes localized blisters at the point of attachment of the traction strips.

These strips should always be applied well above the site of fracture to relax the entire muscle bundle about the fracture. Never should traction be made below the knee-joint, for, in our experience, this has invariably produced troublesome relaxations of the ligaments about the knee and localized the stiffness.

Whenever traction is applied, it should be maximum at the beginning and it should be continuous. The day after application a roentgenogram should be made to show the position of the fractured ends, and, if found in proper alignment, some of the weights

may be removed. A great many workers, however, prefer to have an excess pull so that when the traction is removed and the patient allowed to walk, shortening may not be produced by the retraction that usually occurs in soft callus. As a rule, I believe it is a good point to remember, although "caliper walking" should also obviate this difficulty.

FRACTURES OF THE LOWER THIRD OF THE FEMUR.

In this condition it is essential to place the ice-tong higher up than usual, because the lower fragment is carried backward into the popliteal space by the gastrocnemius muscle. With supracondylar fractures the limb should be put up in flexion in order to obtain neutral muscle pull. This allows free movement at the knee and prevents stiffness of this important joint. These conditions, essential for treatment, can be best obtained by means of a large-ringed Thomas splint elevated at its lower end and secured at the foot of the bed, while caliper traction is made from the condyles. The lower end of the bed can be elevated about twelve inches, after the Hodgkin's method. Should there be any tendency to lateral rotation, it can be effectually controlled by the Sinclair skid.

FRACTURES THROUGH THE CONDYLES.

Poor results are obtained by skeletal traction in these cases, for, in our experience, there is a tendency for the tongs to separate the fragments. The best method of treatment we have found to be the attachment of adhesive or gauze strips glued to the limb in a V-shaped manner, the apex upward and anterior, bringing the strips laterally over the condyles, the knee being kept in flexion and exerting traction from below. This forces the fragments together and maintains a proper pull downward.

If by this method reduction is not complete in one week, open operation should be instituted to properly approximate the fragments. This is especially true whenever the fracture line extends through the articular cartilages. Should the knee-joint be opened during this procedure, we have found that the split petalla approach offers the best results.

AFTER-TREATMENT.

This consists of careful observation and adjustments guided by *x*-ray examination. Massage and electric treatment of the muscles should be instituted on the first day and carried on to the complete rehabilitation to normal. The master band should never be removed. This form of treatment should be continued until bony union has occurred and should be judged chiefly by roentgenograms, although it is well to remembeer that it is not safe to bear any weight upon the limb until localized tenderness has disappeared in the callus at the point of fracture. Backward bowing at the site of fracture should be carefully guarded against at all times, as this displacement, throwing the muscles out of the normal plane of action, causes serious after-derangement of the knee-joint. The ring of the Thomas splint should be observed daily and no over-riding of the tuberosity of the ischium should be permitted.

COMPLICATIONS.

With the advent of the Whitman method and the proper use of the Thomas splint, complications are few. At the point of entrance of the caliper there may develop a low grade ostitis. As a rule, however, this takes care of itself when traction is discontinued. Nerve injuries, although occurring in twelve to twenty per cent. of all cases during the war, are rare in industrial cases. They should, however, be watched for at all times and treated adequately. The same point applies to injuries to bloodvessels, especially of the popliteal artery.

CALIPER WALKING.

The fracture having united, the patient should not be permitted to bear his weight upon the limb until bony union is firm,—otherwise, bowing ensues with shortening, and the results of weeks of careful attention are destroyed. The caliper walking splint allows the patient freedom of movement commensurate with his condition, and will be found a valuable and necessary adjunct to the treatment.

SUMMARY.

I have attempted to outline here the essential points of treatment of fractures of the femur. Many smaller details have been omitted because I feel that each worker will find that certain smaller changes will, if necessary, give him results in individual cases, but there are certain basic facts which I would reiterate in conclusion:

1. Fracture of the femur is a serious process, both in its immediate aspect and in its possibility of permament impairment of function.

2. The Whitman and Thomas splint methods bring almost perfect results if properly applied. The medical profession was slow to take them up but the great war and later experiences in industrial surgery proved their efficacy.

3. Every case should be painstakingly watched. Daily inspection and frequent *x*-ray examinations are as essential as the proper application of the method chosen for treatment.

4. The mobility of the knee should be carefully guarded by free, passive, and active movements and by massage.

I have purposely not entered into the discussion of compound fractures of this bone, because the essentials of treatment are the same as in uncomplicated cases, save for the proper management of the soft parts and any ensuing infection.

234 Consolidated Realty Bldg.

ARTIFICIAL TOES.

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(Formerly M.C., U. S. Army.)
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Those who have been crippled in the recent World War, or before, by the amputation or loss of one or more toes, or metatarsals, and who have suffered the great disability occasioned by the sacrifice of such a small part of their anatomy, will appreciate the appropriateness of considering at this time the subject of artificial toes.

Fig. 1. Foot injured in railroad accident, resulting in loss of great toe and first toe. See figures 4 and 6.

It was while in army service and teaching scientific examination of feet and non-surgical orthopedics for the treatment of ailing feet, rebuilding broken arches, and preventing foot ailments, that I had abundant opportunity to observe the great distress and reduced efficiency occasioned by the loss of even one toe.

So little attention has been paid to the feet generally by the profession that it appears the absence of a part of a foot has not been considered a matter of much moment. Most of the attempts to remedy the condition have been more inconvenient and painful than beneficial. Up to this time the efforts that have been made to devise some method whereby the normal mechanics and physics of walking could be restored to those who have lost some of the anterior portion of the foot, have not been very successful.

The Sunday newspapers recently announced in page articles that one of Ziegfeld's stars had a toe amputated. Let us hope her loss will not detract from her beauty. As ailing feet register their pain lines in the face, and the amputation of even one toe weakens the anterior metatarsal arch, this stage beauty is liable to suffer the same as other and plainer mortals.

RESTORE NORMAL WALK.

This paper is to report results with what may be called "artificial toes" or "substitute toes", because mechanically, anatomically, and instrumentally, they take the place of missing toes. The device here described first came to my notice in an article by Ryberg. It gives so much comfort, and such perfect toe-service, permitting the wearer to do approximately everything that could be done before the loss of any part of the foot, that the term "artificial toes" appears quite appropriate. In addition to the

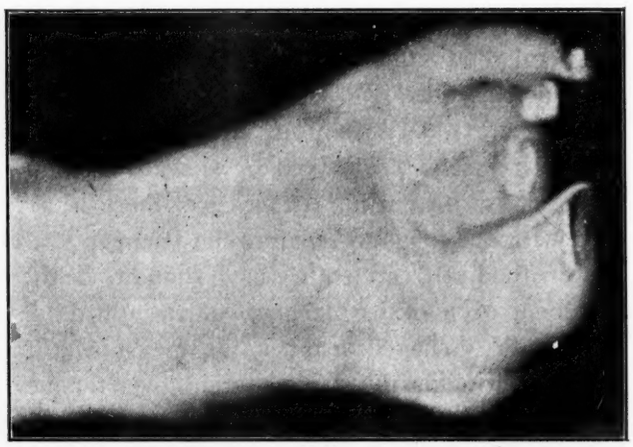

Fig. 2. Foot injured by a heavy weight falling upon it, resutling in loss of the heads of the second and third metatarsals and amputation of fourth toe.

almost normal toe-service, it also gives springiness to the gait by restoring ability to thrust the body forward and walk without limping. It enables the wearers to run, jump, dance, play tennis and, by freeing them from pain, removes the haggard lines that painful feet always cause to be registered in the face.

EASE AND COMFORT.

The artificial toe is incorporated into the shoe and the wearer is not troubled with putting it on, or taking it off, any more than with putting on or taking off a shoe. Its presence cannot be noticed, and it causes no discomfort, nor is there any liability of chafing the foot. When properly adjusted, the injured parts are so protected and supported that the wearers feel the greatest comfort and benefit from the appliance as soon as they begin to wear it.

POST-SURGICAL TREATMENT.

The cases here illustrated came under my observation within a few weeks of one another, and others have followed. Two were industrial accident cases and one was the result of the operation recommended by Morton for what is familiarly known as Morton's painful toe. For each of these patients the

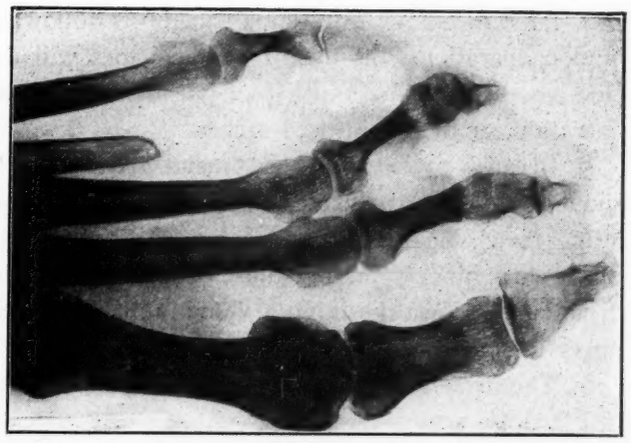

Fig. 3. Amputation of fourth toe and metatarsal head for Morton's toe, followed by chronic pain across the foot because of weakened arches. Under proper treatment, these conditions can be permanently relieved without operation.

surgeons did all that operative surgery could do. But there still remained severe suffering, and a great degree of reduced efficiency. These patients are, therefore, able to speak from experience of the great relief they have gained from the use of the artificial toes and the treatment given to produce

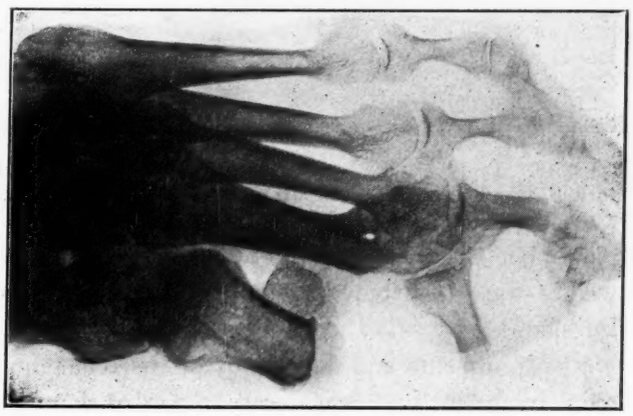

Fig. 4. Roentgenogram of foot shown in figures 1 and 6.

relief and increased efficiency. Their words of commendation have encouraged me to submit this article for publication in the hope that the same benefits may be applied to others similarly afflicted.

AVOID METAL ARCH SUPPORTS.

Attempts at relief by the use of metal arch supports had been made on all patients referred to me, but were unsuccessful. In fact my belief is that they did positive harm and such treatment is always a distinct detriment. The use of any rigid or metal splint material is always sooner or later debilitating to other parts of the body, and experience leads me to believe that the feet are no exception to that rule.

PREPARATORY TREATMENT.

On account of inflammation, atrophy, swelling and tenderness which may occur in an injured foot, the use of metal plates, and the habit of favoring the painful area, some preparatory and antiphlogistic rebuilding or adjusting treatment is always required before fitting the artificial toes. To get the best results, this treatment may run into months. During this preliminary treatment several examinations and surveys should be made to accurately determine the exact location of the axis of the weight-bearing area of the injured foot. This information is secured by studying the surveys and outline tracings which are made around the photo-pedo-graphs of both feet. From tracings properly surveyed and measured,

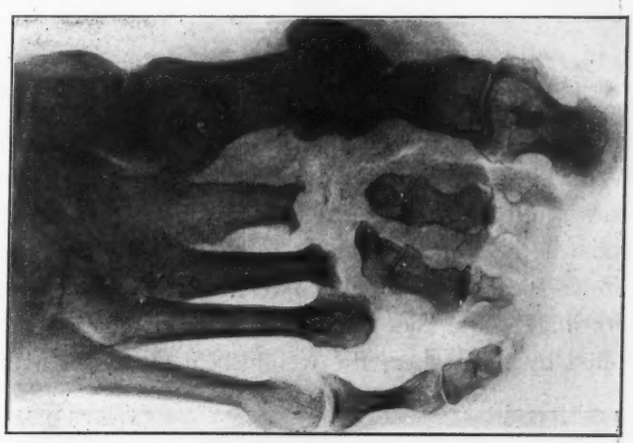

Fig. 5. Roentgenogram of figure 2. See figure 7.

the weight-bearing axis is determined and the exact dimension and shape of the artificial toe can be ascertained and the location it is to occupy in the shoe is indicated.

LOCATING THE WEIGHT-BEARING AXIS.

After ascertaining the location of the weight-bearing axis on the photo-pedo-graph, the outline tracing is cut out and attached along the bottom of the patient's shoe, into which the artificial toe is to be placed. The site of the weight-bearing axis is indicated and marks the location the artificial toe is to occupy in the shoe. This area is then indicated on the bottom of the shoe, and the work is turned over to a skilled shoemaker, who has been instructed how it should be completed.

The outline tracing and the photo-pedo-graph of both feet are made at the same time. The photo-pedo-graph is a reproduction of the impression of that portion of the planter surface of the feet bear-

ing the body weight. It can be made by any method similar to those used to take finger prints.

The plaster-cast method of ascertaining the placement of the artificial toe is to make an impression of the plantar surface of the foot with body weight equally distributed to both feet. This impression can be used as a mould in which to construct a paraffin- or plaster-cast of the injured foot. The exact location of the weight-bearing surfaces are then indicated on the cast, and an estimate of the dimension, shape and location of the artificial toe is made.

ARTIFICIAL TOES.

As the normal foot action has a springiness, the

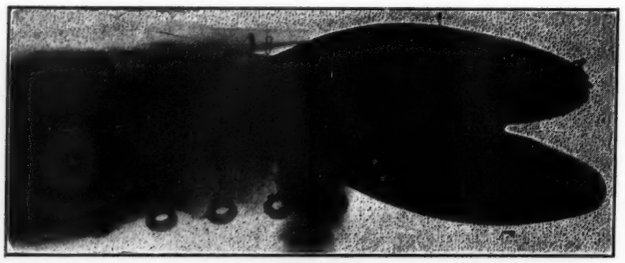

Fig. 6. Roentgenogram showing artificial toes in place. See photograph and roentgenogram of the same foot, figures 1 and 4.

artificial toe construction is for the same purpose. With specially processed spring steel, the artificial toes are made and so fitted along the weight-bearing axis of the injured foot, as to enable it to functionate as nearly as possible like a normal foot. According to the foot survey, as worked out and applied by the writer, the weight-bearing axis can be

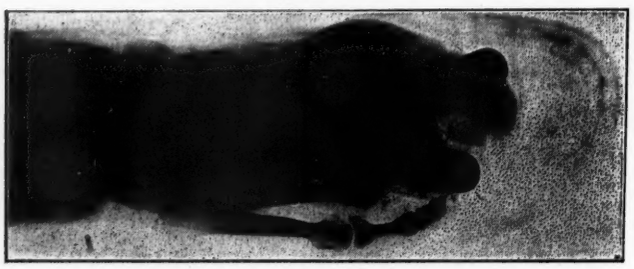

Fig. 7. Roentgenogram of the foot shown in figures 2 and 5, showing artificial toes in situ.

located on an injured foot the same as on a normal foot. A proper distribution of the weight to be supported is the key to success in artificial toe construction, and may be likened to the weight distribution of an ice skater along the steel runner of the skates.

The most serviceable shoes for patients who require artificial toes are those made on the Munson army last. However, experiments are being made with other types of shoes for both men and women.

SUMMARY.

1. Proper size and correct placement of artificial toes under feet from which toes have been amputated may restore normal walk and springiness to step.

2. By relief of the constant strain on injured tissues and destroyed arches, patients are given ease and comfort and their efficiency is greatly increased.

3. Much post-operative suffering can be relieved by artificial toes.

4. As a means of differential diagnosis following bunion operations, the use of artificial toes will decide whether weakness in a foot is the result of the operation, or due to injured arches.

5. Because of their rigidity, metal arch supports should not be permanently used under injured or ailing feet. When held rigid by metal splints, atrophy occurs quickly in foot muscles and adds to the disability, because the internal longitudinal arch was never intended as a weight-bearing area.

6. The weight-bearing axis for the successful

Fig. 8. Photograph of the "skate line" which shows the normal weight-bearing area of a foot, taken from below with the patient standing on a glass support.

placement of artificial toes is the same as if the weight were distributed along the narrow blade of ice skates.

7. All ailments and distortions of the feet require more treatment than is generally accorded them, and it is necessary that the treatment be given, and over a long period of time, to bring about the best results.

FLAT FEET.

The term flat foot is a relative one so far as function is concerned. The foot should be judged by what it can do, rather than by the height of the longitudinal arch. An important phase of the work of orthopedic surgeons in the army was to determine the ability of the foot of an individual to bear strain.—W. L. POWELL in the *Virginia Medical Monthly*.

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WALTER M. BRICKNER, M. D., F. A. C. S., Editor.
New York City

ELMIRA, NEW YORK, SEPTEMBER, 1921.

ORTHOPEDIC SURGERY.

Garrison's History of Medicine tells us that it was Nicholas André who, in his treatise of 1741, "coined the term *orthopedics*". *Orthopedics* and *orthopedic surgery* are generally defined as "the art of treating deformities" or, as Bradford and Lovett would rather have it, "the prevention as well as the cure of deformity". As indicating the scope of the work of those who call themselves orthopedists, the definition is a poor one, since there are many deformities, e. g., congenital malformations of the genito-urinary organs, congenital and acquired deformities of the mouth and face, with which they do not concern themselves. *Per contra,* orthopedics has not limited itself to deformities, since it includes tuberculosis of the spine and joints, which produces "deformities" only as an end-result, and is no more "deforming" than other infectious and destructive processes heretofore usually surrendered by the orthopedic to the general surgeon.

Until very recently orthopedists were occupied in the treatment of a quite limited number of diseases —torticollis, static and nutritional deformities of the spine and extremities (scoliosis, bowlegs, knock-knees, flat-foot), congenital dislocation of the hips, congenital and acquired talipes, tuberculosis of the spine, hip and other joints, the management (by supports, later by tendon transplantations, etc.,) of paralytic deformities. To be sure, some of the elder orthopedists—Sayre, for example—included fractures and dislocations in their work, but such injuries were, and still are, treated more often by the general surgeon.

Until quite recently also, orthopedic therapy was largely conservative, and depended to a very great extent upon the employment of supports, braces and plaster casts.

In both respects, orthopedic surgery is undergoing, indeed, has undergone, a change. The newer generation of orthopedists reaches out beyond this limited list of diseases and is deeply interested in the study and treatment of *all* the affections of the bones, joints, muscles, tendons—congenital, traumatic, inflammatory, neoplastic, paralytic; and it applies to them radical reparative, reconstructive surgery, as well as the preventive and supportive measures of hygiene, exercises and braces. Albee's "Orthopedic and Reconstructive Surgery" is quite representative of this widened scope and newer spirit in orthopedics. Other works, coming out of the war, e. g., Jones' "Orthopedic Surgery of Injuries" and "Chirurgie Réparatrice et Orthopedique", are also suggestive of the growth of this specialty. Indeed, the war itself, in which the general surgeon and the orthopedist were equally occupied in the management of the same casualties, stimulated, though it can not be said to have started, this expansion.

The definition of orthopedic surgery should be changed from "the treatment of deformities" to THE TREATMENT OF AFFECTIONS OF THE SKELETAL STRUCTURES. It is a large sphere, in which there ought to be ample room in civilian practice, as there was in the war, for both the general surgeon and the specialist. It is, too, a most inviting field, replete with interesting problems, pathologic, physiologic and mechanic.

We have planned this issue of the JOURNAL as expressive of orthopedic surgery in its broadened aspect; and we present it to our readers, not merely as interesting in its individual contributions, but also as a stimulant to those specialists who may not yet have caught the spirit of expansion.

We regret that an article on Tendon Transplantation in Cases of Musculo-Spiral Injuries Not Amenable to Suture, contributed for this issue by Sir Robert Jones, was received too late to be included. It will appear in a forthcoming number of the JOURNAL.

SURGICAL FEES.

Much discussion has appeared in the lay and medical press concerning a recent pronunciamento of the trustees of the Johns Hopkins Hospital that surgeons should not (which was a scarcely more pleasant way of saying they *may not*) charge more than one thousand dollars for any operation performed in the hospital, nor more than thirty-five dollars per week for attendance upon any patient therein.

Like most "restrictive legislation"—such as that against alcohol and, in some states, against tobacco—this is probably a reaction to abuses; and it seems safe to assume that on one more occasion there has been charged for an operation performed in the hospital a fee that was, or was thought to be, unreasonable in the circumstances. But if there were abuses, surely they could be corrected without such a sweeping and unreasonable ruling. Whatever its immediate and local purpose, the ruling can be interpreted only as an attempt to establish generally a maximum surgical fee; for it is inevitable that this ruling will be quoted in any court of law in which a surgeon may attempt to collect a disputed, larger fee.

Nor is the decree for the protection of those of moderate means; indeed, for them it will work quite otherwise. It is in the interest of the man of wealth. To him it says: "Though you pay $5000 to the artist of the brush who reproduces your features upon canvas, $1000 is quite enough to pay the artist of the scalpel who with delicate skill changes your living features to your liking, or to him who rids you of a tumor in your brain". We wonder whether any lawyers or engineers who may be trustees of the Johns Hopkins Hospital also considered the establishment of a maximum fee for them to charge in all cases, irrespective of the importance or the skill of their work, the responsibility and effort involved, the wealth of the client!

For the ordinary operations of surgery, under ordinary conditions, fees of more than one thousand dollars are quite exceptional and may well be regarded, in most cases, as excessive. But it should not be intimated by the trustees of any hospital in this country that a charge of more than one thousand dollars for *any* operation upon *any* individual is excessive. No man who can not afford to pay a large fee is denied needed surgical attention; no patient who can not afford to pay any fee whatsoever is denied skilled surgical treatment; and no one, rich or otherwise, need put himself in the way of being charged more than he thinks reasonable and adequate, since it is simple enough to agree upon the remuneration in advance!

It was said, in the discussion of the Johns Hopkins pronunciamento, that the practitioner of medicine should be content with a modest income, should not seek large remuneration for his services. Who knows better than the doctor himself that his life is sacrificial—of ease, of leisure, of pleasures, of peace of mind, of adequate financial returns! But shall the surgeon—or the physician—who has attained unusual skill and eminence be told, therefore, that it is a sort of disgrace for him to seek a large financial reward for his services, no matter what they were, from those who can well afford to pay it?

It seems likely that, if the surgeons at Johns Hopkins or elsewhere, who, by their reputation, attract patients of large means, accept this restriction upon their fees, they will make up for their losses by making larger charges to patients of moderate means and by seeking more of them—in competition with their younger and less eminent colleagues.

But the question of more-than-$1000 fees will irritate the surgical profession at large more in principle than in practice. In the overwhelming majority of cases, after the patient has paid his hospital bills—*strictly in advance,* if you please—he is usually not able to pay his surgeon anything like a thousand dollars. Let us turn, then, to a consideration of the restriction of the surgeon's charge for hospital visits to $35 per week. Assume the case of a man, with a fracture of the femur, occupying a room at $10 per day. His surgeon does not operate upon him, but he spends many hours in adjusting and readjusting the suspension-traction apparatus, in *x*-ray examinations and in all the other minutiae of supervision and treatment that such a case always requires. At the end of eight weeks in the hospital this patient *will have paid* to the hospital, for his board and lodging and the board of two nurses, $672, to each of these two nurses $336 (a total of $1,344—perhaps more), and he *will owe* to the surgeon who has borne the brunt of the work and *all* of the responsibility the princely reward of $280! Can the Johns Hopkins trustees seriously mean that for all post-operative visits, no matter how many may be needed or how time-consuming they may be, the surgeon should charge not more than five dollars per day, that if his patient is sick enough to require his constant attendance the surgeon should charge less than he pays his chauffeur (if he is disgracefully prosperous enough to employ one)? Surely not. Probably all that is expected is a mere letter of explanation for consideration by an indulgent board of laymen!

The preparation for a medical career is becoming more and more difficult, more and more costly in years and in money. The practice of medicine is every year being harrassed with more and more regulations, restrictions, licensures—conceived for the most part in the public interest, but often with little regard for the physician.* Some of our legislatures have dragged the practice of medicine, in the eyes of the public, down to the level of osteopathy, chiropraxis and perhaps other "cults" that are based on unproved and unproveable dogmata—the very thing from which medicine struggled in centuries gone by. And now the trustees of one of America's leading hospitals have undertaken to regulate the physicians' fees—not in the interest of the medical men who give of their time and their skill to the institution, but, forsooth, with a considerate eye to the pocketbooks of its wealthy patients. It all reminds us of an apt, but unprintable, remark, probably familiar, that is said to have been made by an attorney concerning his client, a large corporation that was perpetually pestered, restricted, taxed by every governmental agency that could find an excuse for hampering it. It reminds us, too, of a once familiar song. If the practice of medicine is to have the dignity that the welfare of the public requires for it, then,—to slightly paraphrase the title of that song—"you'd better quit kicking your dog around"!

*Witness, for example, the absurd and cumbrous regulations for the prescription of habit-forming drugs, established by the sometime N. Y. State Commissioner of Narcotic Drug Control.

Surgical Suggestions

In all cases of talipes, congenital or acquired, examine, by palpation and roentgenographically, for an occult spina bifida.

There are two inflammatory bone conditions that should be thought of as possible causes of persistent pain in an extremity not otherwise explained—syphilitic periostitis and chronic bone abscess. Both are tender on pressure.

Chronic, sterile, central bone abscess, large or small, can be cured by simple evacuation through a small drill hole. Introduce no instrument or drain into the cavity. A small drain may be placed in the muscles. The operation can be performed under nitrous oxid.

Progress in Surgery

Selections from Recent Literature

H. Lyons Hunt, M.D., L.R.C.S. (Edin.), Abstract Editor.

Rib Pressure and the Brachial Plexus. Edwin Bramwell and Harold B. Dykes. *Edinburgh Medical Journal,* August, 1921.

In this very interesting article Bramwell and Dykes show that: the same symptoms as may be produced by a cervical rib may also be caused by the pressure of an abnormal or *even by an apparently normal first dorsal rib,* and can be cured or relieved by removal of part of the rib; that cervical ribs often exist without symptoms; that those giving symptoms are usually in females; that the numbness and tingling of the fingers, especially the fourth and fifth, commonly complained of by women and often regarded as circulatory in origin, may be traceable in many cases to rib pressure on the plexus.

The article should be read in full. We extract the following significant passages:

Unilateral Pressure Symptoms: no Cervical Rib. Removal of First Dorsal Rib; Recovery.—A typist, 24 years of age, had been troubled for seven years with pain along the inner side of the left forearm which had necessitated her giving up her occupation. Upon examination, some weakness of the left hand and slight flattening of the thenar eminence were observed. Tenderness was complained of on pressure in the region of the transverse process of the seventh cervical vertebra on the left side. No definite sensory loss was detected nor was any difference between the radial pulses noted. The *x*-ray examination showed no evidence of a rib anomaly, although the transverse processes of the seventh cervical vertebra on either side were somewhat prominent. Rib pressure was diagnosed and Sir Harold Stiles decided to remove a portion of the first rib, an operation which was followed by immediate disappearance of the pain and by gradual improvement in the motor weakness.

Stiles has carried out the same operation in several cases of rib pressure with most satisfactory results. We have personally observed several cases in which symptoms which we attributed to rib pressure were not associated with a demonstrable cervical rib. Proof that pressure symptoms may be caused by an apparently normal first dorsal rib is afforded by the fact that in certain cases which have been operated upon, removal of the rib has resulted in the disappearance of symptoms. Objection might be taken to this conclusion on the grounds that in these cases the pressure is actually produced by the ligament which sometimes passes from the apex of the cervical rib to the first rib to which it is attached. If this is so, removal of that portion of the first rib, which includes the attachment of this ligamentous process, might be expected to relieve pressure just as readily as division of the band itself. On the other hand, in more than one case which we have observed, neither did the *x*-rays show any abnormality of the transverse processes of the seventh cervical vertebra, nor was any evidence of such a band found on operation.

Factors which Determine Symptoms

Pressure symptoms are observed only in a small proportion of individuals with cervical ribs. Borchardt states that they occur in five to ten per cent. Consequently, while it must be admitted that variations in the formation of the brachial plexus may predispose to rib pressure, additional factors must be responsible for the determination of symptoms. In this relation *sex* is evidently of the first importance. Although there is no evidence, so far as we know, to show that cervical ribs are more frequent in women that in men, the greater frequency with which symptoms of rib pressure are observed in the female as compared with the male sex is striking. Thus twenty of our twenty-three patients were women, an experience similar to that of other observers. Thorburn, for instance, met with only two males in a series of 17 cases, while fourteen of Hinds Howell's sixteen patients were

of the female sex. Hinds Howell suggests that the more thoracic type of respiration in the female may be a determining factor. Wingate Todd has shown that in females a pronounced dropping of the shoulder girdle takes place in early adult life, and his suggestion that this may afford an explanation of the unequal affection of the sexes is an attractive one.

Brachial plexus lesions due to rib pressure may be conveniently classed, from the point of view of diagnosis, into two groups, viz.:—(1) Cases in which symptoms referable to the first dorsal root or lower cord of the brachial plexus are evidently caused by rib pressure, and in which a cervical rib or a rudimentary first dorsal rib can be demonstrated, and (2) cases in which the same group of symptoms is unaccompanied by any evidence of a rib anomaly, the symptoms being due to pressure by a normal first dorsal rib.

Again, a variety of types may be distinguished:—(*a*) Cases characterised by sensory, motor, and it may be vasomotor symptoms; (*b*) Cases in which pain and other subjective sensory phenomena are alone complained of, there being no objective sensory or motor disturbance; (*c*) Cases characterized by muscular weakness and wasting, pain and other sensory phenomena being either absent or inconspicuous features; (*d*) Rare cases in which vasomotor disturbance is the striking morbid manifestation; (*e*) Cases in which acroparesthesia and pain in the hand and fingers are associated with and apparently produced by rib pressure (Farquhar Buzzard).

A diagnosis may be difficult in cases in which there is no pronounced atrophy or sensory loss. The occurrence of pains from time to time in one or it may be both upper extremities, particularly in a young woman, should always suggest the possibility of rib pressure. When on further inquiry it is ascertained that the pain is confined to the forearm and that it is accompanied by other subjective symptoms, such as coldness in the hand, numbness or tingling in the finger-tips, and "pins and needles," referred especially to the little and ring fingers, possibly too by a feeling of weakness or clumsiness in the hand, the strong probabilities are that the symptoms are attributable to this cause. Corroborative evidence in support of the diagnosis is afforded when a history is obtained to the effect that the pain is relieved by raising the arm above the head, when there is localized tenderness in the neck, and when there is a difference between the radial pulses on the two sides. In a certain proportion of cases, the demonstration of a cervical or rudimentary first dorsal rib by the *x*-rays affords practically conclusive proof as to the nature of the condition. *It is to be remembered, however, that a diagnosis can and must in many cases be arrived at from the character of the pressure symptoms, for corroborative evidence is by no means always afforded by the x-ray examination.*

Cases of rib pressure in which the symptoms are not pronounced may sometimes be materially benefited by attention to the general health, and do not call for surgical treatment. When pain occurring from time to time is alone complained of, this symptom can usually be relieved by a sling which supports the elbow, while a blister above the clavicle may be helpful. Stopford lays stress upon the development of the trapezius muscle by exercise and faradic stimulation, with the object of counteracting the dropping of the shoulder-girdle. When pain due to rib pressure is so severe as to cause constant annoyance, or when pain or muscular weakness, or both, are producing such inconvenience as to interfere with the patient's occupation, surgical intervention is indicated.

The results of operative treatment in those cases in which pain is the prominent symptom are most satisfactory, for the pain is usually completely relieved. Thus, of 15 cases reported by Thorburn, in all of which pain was present, this symptom was completely cured in 12 and relieved in 3. Again, Sargent, whose experience has probably been unique in this department of surgery, reports that in all of the 5 cases he had met with in which there was bilateral pain, the patient returned to him at a later date and asked to have the opposite side operated upon. Paralysis, which was present in 12 of Thorburn's 20 cases, was completely cured in 5 and greatly relieved in 5, while 2 cases were not traced. When there is pronounced wasting of the hand muscles, complete recovery cannot be expected. Ill-effects occasionally result from surgical intervention. Thus the pleura may be opened, while the suprascapular nerve or the nerve to the serratus magnus or trapezius may be injured. Again, if the superficial branches of the third and fourth cervical nerves are divided, the patient may, for long afterwards, suffer from intense pain in the region of and below the clavicle. Further, the brachial plexus may be injured in the course of the operation as in two cases referred to by Sargent, in both of which there was complete paralysis of the upper limb, which was probably due to bruising of the plexus. In neither case was recovery complete six months after the operation.

Discussion on Bone Surgery in the Section of Surgery, British Medical Association, July 21, 1921. Summary of Proceedings, from the *British Medical Journal,* August 6, 1921.

Naughton Dunn discussing *Compound Fractures* of the lower extremity attempted to lay down definite lines on which compound fractures and their complications should be treated in civil life. Emergency treatment included immediate application of a sterile dressing, a tourniquet, if necessary, and a Thomas splint suspended at its end for comfort in transport. It was a safe rule to operate on these cases early. The object was to remove all severely damaged tissue, muscle and skin and detached fragments of bone; to wash the wound thoroughly with an aseptic solution, then with spirit, and then to apply a film of bipp to all the wound surfaces; the wound was then to be sutured with drainage. Antitetanic serum was to be given as a routine in all cases of compound fracture. Alongside operation came treatment by splintage, and he believed that the Thomas splint met all the requirements for fractures below the upper third of the femur. He mentioned also the Jones abduction frame, Pearson's sectional bed for use with the Thomas splint, and the Sinclair net bed in the oblong wooden frame. At the end of ten or twelve weeks splints could be discarded and a caliper splint worn for weight bearing.

Dunn discussed also compound fractures involving joints, and their effect on the joints when not involved. In dealing with chronic sepsis following compound fractures he showed that, if operation were contemplated, it must be a radical one, and only to be carried out if the general health of the patient were good, if there were no signs of local reaction, absence of rise of temperature for three months, and a history of only slight reaction after previous operations. The operation consisted of excision of the sinus, long incision, free exposure of bone, removal of bone till all sequestra were exposed, and the cavity converted into a groove, spirit and bipp treatment as in the primary operation.

Subsequent speakers showed some diversity of opinion as to the value of the Thomas splint, the necessity for administration of antitetanic serum, the immediate and remote results of caliper extension. All were agreed that the compound fractures of civil surgery were in many respects different from those of war. Edington (Glasgow), Wade (Edinburgh), and Hamilton Russell (Melbourne) did not regard the extreme operative measures of the war as generally applicable to compound fractures of civil life. Fullerton (Belfast) recommended excision of the wound, avoidance of antiseptics, and extension of the caliper method.

Hamilton Russell in a short paper gave his views on theory and method in extension of the thigh. The muscles from the pelvis to the head of tibia and fibula prevented adjustment of the fracture, and it was of importance to overcome the resistance maintained by those muscles. This was best accomplished by a pulley arrangement whereby longitudinal extension of the leg was supplemented by vertical extension by a sling at the knee level, the resultant of these two forces being a pull on the lower fragment in the best possible line. He was by no means whole-heartedly in favour of the Thomas splint. It added to the weight of the limb, its extending force depended

upon pressure on a portion of the patient's body; that meant it was uncomfortable, and if it was not uncomfortable it was not efficient.

Bone Grafts.—Mr. Marcus Mamourian (Ashton-under-Lyne), propounded the theory that all that the graft did was to supply the biochemical stimulus or irritant which had been abolished by trauma or infection, the new bone being formed by the diaphyseal ends, by periosteal and bony reamains in the shaft zone and in the young by epiphyseal lengthening, and he supported the theory of Murphy that the graft was ultimately absorbed. A large number of *x*-ray photographs were shown to support the thesis, which he put shortly in three points: (1) That the bone graft acted as a stimulant to the surrounding tissues; (2) that when the graft did succeed in persisting in the presence of infection, the success was not due to its own resisting power but to the fact that the infection was itself a stimulus; and (3) if there were no visible or palpable growth it was not evidence that there was no bone; it simply meant that the graft was dormant, its bone-forming properties inhibited by trauma or disease. It was important to note that a double action might be in process—bone formation at the proximal end and bone absorption at the distal end.

Fracture of the Forearm in Children. JACOB GROSSMAN, New York. *The Journal of Orthopedic Surgery,* May, 1921.

The author summarizes his article thus:

1. Where, for any length of time, infants and children refuse to use their forearms, after having sustained an injury, fracture should be suspected.
2. Colles' fracture occurs rarely in infants and children.
3. Fracture may be present, even though the cardinal signs of fracture are lacking. These fractures are usually of the subperiosteal variety. "Pencil" tenderness is the diagnostic sign.
4. Epiphyseal separation of the lower end of the radius should be looked for in all cases with injured forearm. It occurs often enough to be considered.
5. Plaster of Paris bandages are by far more efficient than splints and should be given the preference in the treatment of fractures.
6. Proper immobilization is as important as proper reduction in obtaining a successful issue in the treatment of fractures.
7. Shorter periods of immobilization, early massage and passive movements should be employed in children.
8. A pad between the shafts of the fractured bones, as recommended by many, for the purpose of preventing fusion of the fractures, is unnecessary as it could not separate the bone ends without exerting injurious pressure upon the circulation.

The Non-Operative Treatment of Scoliosis. WALTER TRUSLOW, Brooklyn, N Y. *The Journal of Orthopedic Surgery,* May, 1921.

Truslow describes the methods of examination, mensuration and exercising, and concludes:

1. Successful treatment of structural scoliosis must depend upon a clear understanding of the elements of deformity, and the lessening, if not complete elimination, of all of them.
2. Uniform and regular measurement and numerical record of the elements of deformity are important as guides to continuance of treatment and as indicating elements most needing correction.
3. A balanced use of corrective plaster-of-Paris jackets, of retention brace and of intensive exercises is essential to satisfactory results.
4. The position of the patient when the plaster jacket is applied is responsible for improving body posture and shoulder carriage; the successive paddings, for care of the spinal deviation and the rotation.
5. Essentials of a retention brace are (a) ability to hold correction attained; (b) application by the patient with reasonable accuracy; (c) extensibility and lateral compressibility to meet normal growth and progressive deformity decrease; (d) mechanical self-correction by the brace seems possible, but not yet fully attained.
6. Gymnastic exercises must be progressive, intensive and with a minimum of erect weight-bearing. They must aim to correct all of the elements of deformity, especially that of rotation. Starting positions other than standing facilitate these ends.
7. Retention of deformity correction attained must be maintained while exercise is developing natural muscular support. Artificial support may gradually give way to natural support. The paralytic scoliotic must receive a larger proportion of artificial support than will be required for those not paralyzed in the trunk muscles. Internal splinting, by operative bone-fixation, may also be necessary in severe paralytic cases.

Some Aspects of the Mechanism of the Human Foot in Walking. ALEXANDER GIBSON, Winnipeg, Canada. *The Journal of Orthopedic Surgery,* May, 1921.

After describing the mechanism of the foot in walking Gibson says, of heel-walking:

The heel is brought first of all to the ground with the foot in dorsiflexion, and from there the weight is transmitted to the outer spring of the foot almost entirely. The weight is thus mainly borne by the short hard spring. Next the weight is gradually transferred across the heads of the metatarsals to the inner side of the foot. A gradual roll of small amplitude accomplishes this. The under surface of the os calcis is curved, and the fibro-fatty tissue between the bone and the skin acts as a yielding cushion. The cuboid bone is wedge-shaped, the small side of the wedge facing outwards, and the result of pressure on the outer spring must be to press this bone inward to a slight extent, thus transmitting some of the shock of impact of foot on ground to every bone of the tarsus and metatarsus. At the completion of the second stage, the foot is balanced momentarily on the tripod consisting of the os calcis posteriorly, the heads of the fifth and first metatarsals anteriorly. From this point onward all the weight is taken on the inner spring. The head of the first metatarsal sustains all the weight of the body in the take-off for the next step. The long flexible inner spring acts for the succeeding step the role of a diving board. The line of transmission of weight is along the first metatarsal shaft to the base, then through the interosseous ligament to the base of the second metatarsal which is recessed between the first and third cuneiforms, then through the second cuneiform to the central part of the scaphoid, and through it to the astragalus and so to the bones of the leg. The middle cuneiform and the central part of the scaphoid are thus the key bones of the inner spring of the foot. The middle cuneiform is buttressed on either side by the first and the third cuneiform bone and the scaphoid is similarly buttressed by the strong inferior calcaneo-scaphoid ligament below and by the external calcaneo-scaphoid ligament on the outer side.

The use of a heel on the boot involves a sacrifice of stability. But since the ground we tread is for the most part smooth, and comparatively free from obstacles, a small sacrifice of this may be made with impunity. If it be admitted that the use of a heel to the boot economises expenditure of energy in locomotion, it will be seen that the use of a heel of moderate height is a measure of practical utility. More important than the height of the heel is its area. This should always be large. For practical purposes a heel not exceeding an inch or an inch and a half in height permits of active use of the calf muscles, does not excessively throw the weight forward, and yet takes off a considerable portion of the muscular strain of walking. One must bear in mind that in walking the minimum of muscular effort is made. If sufficient is called for to produce tiring of the muscles, the result will be that more and more weight will be thrown on the ligaments, the muscles themselves will be used as ligaments, and there will be consequent stretching with development of the symptoms of foot strain. This is well seen in the case of ballet dancers who are said to be for the most part flat footed. They have developed extreme flexibility of the joints of the foot, along with excessive muscular power. When necessary the arch of the foot can be formed in exaggerated degree, but when off guard as it were, they tend to use the muscles as ligaments, and the foot is correspondingly flat.

As a further corollary, it follows that the boots used should be long enough and wide enough to give free play to the intrinsic muscles of the foot, they should be in no respect splints for the foot, and active development of the foot muscles is likely to provide the best safeguard against the painful condition known as "footstrain."

Reconstructive Surgery of Traumatic Foot and Ankle Deformities. Albertus Cotton, Baltimore, Md. *The Journal of Orthopedic Surgery*, May, 1921.

Of the treatment of traumatic weak foot following imperfectly reduced Pott's fracture, Cotton says:

This deformity gives the typical symptoms of rigid weak foot—pain on changing from a resting to an active position, weakness, lameness and stiffness. While the symptoms of these deformities of the foot are practically the same as those of rigid weak foot due to spasm or actual contracture of the peroneal tendons, the treatment must be different. Tenotomy of the peroneal tendons with wrenching and breaking up adhesions on the outer border of the foot will not cure or relieve the symptoms of this condition. It is necessary to restore the alignment of the foot to the leg, to put the foot back in gear with the leg. The astragalus must be pushed inward so that a line from the tubercle of the tibia passing through its center will pass through the space between the second and third toes. This can be brought about either by osteotomy of the tibia and fibula above the old fracture or by re-fracturing the bones at the site of the old fracture. Simple osteotomy of the tibia and fibula above the old fracture is a simple operation and is quite effective in restoring function in the majority of cases. The cosmetic effect is not all that could be desired. Re-fracturing through the site of the old fracture of the internal malleolus of the tibia and fracture of the fibula has several advantages over osteotomy. It is a more direct attack upon the deformity at the seat of the trouble. At the same time that the bones are refractured the adhesions about the tibio-fibular joint can be broken up and the astragalus, together with the lower fragment of the fibula, pushed inward to its normal position. After obtaining this reduction it is frequently necessary to nail the internal malleolus of the tibia in place. It is usually not necessary to use any other mechanical aid to reduction except to hold the posterior portion of the foot adducted and at a right angle to the leg while the cast is being applied.

Arthrodesis of the Sacroiliac Joint. A New Method of Approach. M. N. Smith-Peterson, Boston, Mass. *The Journal of Orthopedic Surgery*, August, 1921.

The steps of the operation are as follows:

1. Curved incision from the posterior superior spine along the crest of the ilium, two-thirds of the distance to the anterior superior spine. This incision is carried down to the bone and the reflection of the periosteum started.

2. Incision from the posterior superior spine in the direction of the fibers of the gluteus maximus for a distance of three to four inches. This incision is carried down through the subcutaneous fat and gluteal fascia and the muscle fibers of the gluteous maximus separated by blunt dissection, until the junction of the ilium and sacrum, between the posterior superior and posterior inferior spines is reached. In carrying out the dissection, one point should be kept in mind: the superior gluteal nerve and artery emerge at the anterior portion of the sacro-sciatic notch and give off posterior branches which are encountered by the straight limb of the incision, and sometimes cause considerable bleeding. They have to be sacrificed in order to get a satisfactory reflection.

3. The flap thus outlined is reflected subperiosteally, exposing the posterior portion of the lateral surface of the ilium.

4. If the sacro-iliac joint is projected on the lateral surface of the ilium, it will be found that the inferior border corresponds with the sacro-sciatic notch, and the anterior border with the median gluteal line. The superior border is not of importance, because the two above landmarks determine the location of the joint sufficiently. A window is now cut through the ilium within the projected area of the joint. A rectangular window has been used in the majority of cases. The thickness of the ilium just above the sacro-sciatic notch is considerable, sometimes as much as an inch, but if care is taken, the entire block of bone from the outer to the inner table of the ilium may be removed in one piece. The operator is rewarded for his labor, when, upon removal of the window, the cartilaginous joint surface of the sacrum comes into view. The cartilage of the sacrum as well as its cortex is next removed, bringing about a good exposure of cancellous bone. The above procedure results in a rectangular channel bordered on all sides by cancellous bone, extending from the ilium through the sacro-iliac joint into the sacrum.

5. After removing the cartilage and cortex from the block of bone removed from the ilium, this is replaced in its original site and countersunk, so that its cancellous surface will be in contact with the cancellous bone of the sacrum.

6. The flap is now returned to its place and periosteum and soft parts sutured in layers.

The position of the window should be varied according to the case encountered. In purulent infections of the joint, the window is cut in a direction parallel to the sacro-sciatic notch; this will give efficient drainage of the joint. In cases of tuberculosis, it is better to cut the window at an angle as a better dowel is thus obtained. This, of course, also holds true in cases of sacro-iliac relaxation.

In cases of tuberculosis, the above description does not hold absolutely true, as the curette has to be used extensively to reach the parts of the joint not actually exposed. Seven cases of tuberculosis of the sacro-iliac joint have had arthrodesis of the above type during the past three years, with uniformly gratifying results. Cases of relaxation of the sacro-iliac joint which have had the above type of arthrodesis performed, have also been uniformly successful. They are, however, only six in number, three of them too recent to judge.

Manipulation of Stiff Joints. Sir Robert Jones, Liverpool, Eng. *The Journal of Orthopedic Surgery*, August, 1921.

A painful joint which is rigid in all directions is the seat of an arthritis, while a painful joint which is rigid in certain directions only—movements being normal in others—is free from arthritis. This is more obvious in joints such as the wrist, shoulder, hip and spine, which have a comprehensive range of movement, than in joints such as the elbow, ankle and knee, where the movements are practically limited to flexion and extension.

If there be no limitation of movement in a suspected joint, there is no arthritis. In early cases the rigidity must be examined for without an anaesthetic, as it is primarily due to protective muscular fixation. Later, contractures or muscle shortening will follow as secondary effects, but by then a diagnosis will be obvious. One illustration will suffice to make this clear. A girl complains of pain in the dorsolumbar region of her spine. The surgeon asks her to flex, extend, rotate and laterally move her spine. If she can do so she has neither adhesions nor arthritis. Another may have great tenderness over her spine, and is unable to fully flex or laterally deviate her spine, but she can hyperextend. This case can be assumed free from arthritis and may probably have adhesions. A third case is rigid in every direction, and her condition may be diagnosed as an arthritis.

This classification requires modification when we deal with fractures into joints with bony blocks, or with myositis ossificans in the muscles surrounding a joint.

Adhesions may be divided into two groups—(a) intra-articular; (b) extra-articular.

Intra-articular adhesions may be the result of rupture of joint capsule, of hemorrhage, or of the plication, with adhesion, of the synovial membrane. Rupture of the intra-articular ligaments, such as the crucial and ligamentum teres, do not give rise to adhesions which require surgical attention.

Extra-articular adhesions may be connected with the capsule, the ligaments, muscular origins or insertions, rup-

ture of the muscular fibres or blood extravasation into tendon sheaths. Stiffness of the joint may also be the result of adaptive muscular shortening, physiological in character, or it may be due to loss of resilience in the sheaths surrounding muscle and muscle fibre.

Prolonged immobility of a healthy joint will result in temporary stiffness, which is usually due to adaptive shortening of soft structures, and this can be rectified without forcible manipulation.

Light adhesions may be broken down under gas, or gas and oxygen; if strong and resistant, full anaesthesia is best. Complete muscular relaxation is rarely obtained under gas, and, in consequence, the surgeon is less able to gauge the force he should apply. The joints should be moved through the full anatomical range unless the adhesions are extremely firm. If firm and resisting, the movements should be less complete, and full mobility should be secured in stages. The advantage of the use of gas is that the movements may be voluntarily practised almost at once, and this is of considerable psychological advantage. After all adhesions have been overcome, and while the patient is asleep, the limb should be placed in the position of full correction until he recovers consciousness and is able to make a voluntary effort. This helps to emphasize the right of way, and furthermore, has a good mental effect, for the patient, when he becomes conscious, realizes that the obstruction has been overcome. The earlier movements are practised after manipulation the better, for the pain is less acute and the results more rapid and effective. If, however, the manipulation has been very severe and reaction is feared, it is advisable to fix the limb for a few days in the corrected position in order to rest the assaulted joint, massage being substituted for movement.

The normal range of movements in a joint varies in different people and at various ages. It is advisable, therefore, during our manipulation of any joint, to compare its range of movement with that of the opposite side. Unless this is done, it is easy to produce a sprain.

If, as a result of manipulation, the range of movement is diminished, it is fair to conclude that the after-treatment has been defective, or that the manipulation has been ill-advised. After the joint has been conducted through its complete range of movement once, it is useless and harmful to repeat the procedure. The "pump handle" method, as applied to the breaking of adhesions, or the practice of passive movements, is to be avoided. Voluntary efforts, however, can be repeated with advantage as often as the patient can be persuaded to make them.

Passive movements and the breaking of adhesions by manipulation in the presence of fracture near a joint, should be most carefully performed. The fracture should be adequately protected from strain by closely applied splints.

If effusion should take place in a joint after manipulation, it is strongly suggestive of the rupture of intra-articular adhesions. Such effusion does not necessarily imply that the manipulation should not have been employed *unless* the effusion is accompanied or followed by a diminished range of movement. If the range of movement is diminished by use and exercise, the joint requires rest. If, even in the presence of pain, the range of movement is increased by exercise, rest is contra-indicated.

The rupture of typical adhesions is heard and may be felt under the hand. If no click is heard or felt, but the resistance is overcome by a gradual stretching, the prognosis is not so good, and the joint should be retained at rest for a few days in its new and corrected position. Passive movements should then be gently practised. Pain which is sharp and of short duration is negligible, but if pain continues for protracted periods, it means a reaction likely to be followed by increased stiffness, and calls for rest.

Diagnostic and Therapeutic Point in Retrocalcanean Bursitis. A. L. NIELSON, Harlan, Iowa. *Journal of the A. M A.*, August 6, 1921.

This bursa is subject to the usual affections of bursae in general. Of special infections, tuberculosis occurs, and when it does occur, it extends to the bone quite readily, owing to the thinness of the bursal wall in its anterior and upper aspects. Gonorrheal infection attacks this bursa, as do rheumatic infections. In chronic infections of the bursa, there is a thickening of the bursal endothelial lining. There may be cartilaginous hypertrophy and periostitis, with formation of exostoses. Effusion is rare. Direct infection by puncture wounds may occur.

The causation of disease of this bursa may be classified as: (1) functional, (2) traumatic and (3) bacterial. Overuse of the foot, too much walking, the trauma incident to pressure of shoes, usually too short shoes, are etiologic factors in most cases. Bacterial infection is chiefly metastatic, the disease being, on this account, very often bilateral.

Pain is localized at the junction of the Achilles tendon and the os calcis. This pain is only on motion; rest relieves, and there is more comfort with the foot everted and the leg rotated outward. There may be tenderness over the bursa, and often there is an appreciable swelling or a doughy mass on each side of the Achilles tendon. A diagnostic point, also valuable as a therapeutic measure, was suggested by J. B. Murphy. The pain is due to the pinching of the inflamed and enlarged bursa, between the Achilles tendon and the os calcis, on flexion of the ankle. If in any suspected case removal of this pressure relieves the pain, we may conclude that retrocalcanean bursitis is the condition with which we are dealing. This is accomplished by putting the patient on high heels, mechanically increasing the distance between the tendon, just above its insertion, and the os calcis, thus giving more room to the bursa and preventing pinching between tendon and bone, as occurs in ordinary flexion of the ankle. Nielson had a three-fourths inch rubber heel added to the ordinary low leather heel.

Roentgen-ray findings are negative in the absence of exostoses. Treatment of this condition, aside from the foregoing method, is surgical removal of the bursa. The presence of long continued inflammation, cartilaginous bodies, or exostoses requires operation. Careful fitting of shoes is necessary to prevent pressure on the heel over the bursa. Local treatment is of little value. Robert Jones reports results with actual cauterization of the bursa, by inserting a heated needle into the bursa.

Autogenous Bone Transplantations. MELVIN S. HENDERSON, Rochester, Minn. *Journal of the A. M. A.*, July 16, 1921.

The cases studied comprised 413 patients subjected to the operation of transplantation of bone. One hundred and sixty-six of the patients were operated on according to the method of Albee for tuberculosis of the spine, and 247 were operated on for ununited fractures, bony defects, etc. One hundred and thirty-two patients with tuberculosis of the spine operated on more than eighteen months before have been definitely followed. Sixty-six (50 per cent.) may be regarded as cured or as having the disease arrested; twenty-nine (22 per cent.) were improved; twenty-two (16.66 per cent.) were unimproved; twelve (9 per cent.) died later, probably of disseminated tuberculosis; three (2.26 per cent.) died so soon after the operation that their deaths must be classed as operative mortalities. The operation is advised only in adults. Four (2 per cent.) developed infection in the wound in the spine; there were no infections in wounds in the leg. Two grafts were lost.

Two hundred and twenty-three of the 247 patients operated on for ununited fractures, etc., were traced. In 177 (79.3 per cent.) the operations were successful, and forty-two (18 per cent.) were failures. Four (1.7 per cent.) of the patients died. Two hundred and forty-one operations were necessary to obtain these successes; thus, the 73.4 per cent. successes are based on the number of operations rather than on the number of patients. In contrast to the spinal cases, which were better than the average in any group of clean cases, the percentage of infections ran high. Thirty-nine (15.7 per cent.) of the 247 patients developed infections. Two hundred and one had clean wounds. Many of them had been operated on before without suppuration, but often with considerable scarring; twenty (9.9 per cent.) of these became infected. Forty-six patients had been infected previously, although apparently the

wounds were clean at the time of operation, and in nineteen (41.3 per cent.) suppuration followed surgical interference. These infections caused the loss of the graft in fifteen cases (6 per cent.), and in almost all a persistence of the nonunion. The technic used in the spinal transplant was used in the fracture transplants. In the first group the percentage of infections is considerably below and in the second, above normal. I believe, therefore, that the cause of the infections rests on the type of case rather than the technic. Possibly a two stage operation would lower the percentage of infections.

The percentage of successes in operations on the various long bones was: tibia, 89.4; ulna, 81.2; radius, 78.4; humerus, 69.6; femur, 57.5. The massive graft with beef-bone screws to hold it in place has given better results than either the intramedullary or the inlay graft.

Book Reviews

On Bone Formation. Its Relation to Tension and Pressure. By DR. MURK JANSEN, O.B.E., Lecturer on Orthopedic Surgery, University of Leiden (Holland). Octavo; 114 pages; 54 illustrations. Manchester: THE UNIVERSITY PRESS. London, New York, Bombay, etc.: LONGMANS, GREEN & Co., 1920.

This monograph, illustrated with excellent photographs of bone sections, is concerned, not with the problems of bone regeneration, but solely with bone architecture. The thesis is a contradiction of the dicta of Culmann, Meyer, Wolff and Roux that tension as well as pressure determine the lines of internal bone structure.

Injuries to Joints. By COL. SIR ROBERT JONES, C. B., CH.M., D.Sc., Inspector of Military Orthopedics, Army Medical Service. *Second Edition.* Duodecimo; 195 pages; 29 illustrations. London: HENRY FROWDE; HODDER & STOUGHTON, 1920.

This admirable little "Oxford War Primer" is, or ought to be, thoroughly familiar to the English-reading medical profession. The general surgeon, the orthopedist, the general practitioner who has not read it has missed something! It is a *multum in parvo,* indeed; almost every page is replete with valuable instruction. The changes in this edition consist in the interpellation of a new paragraph here and there, enlarging the primer by nine pages.

Die Örtliche Betäubung. Ihre Wissenschaftlichen Grundlagen und Praktische Anwendung. Ein Hand- und Lehrbuch von PROF. DR. HEINRICH BRAUN, Geh. Medizinalrat, Direktor des Krankenstiftes in Zwickau. *VI Auflage.* Octavo; 508 seiten; 213 abbildungen. Leipzig: JOHANN AMBROSIUS BARTH, 1921.

In the sixth edition of this very complete, precise and well illustrated work on regional (including local) anesthesia, spinal and sacral anesthesia are dealt with at length, novocain poisoning is described fully, and there is an appendix of forty solid pages of classified bibliographic references. The work is a painstakingly comprehensive one.

A Text-Book of Pathology. By ALFRED STENGEL, M. D., Sc. D., Professor of Medicine, University of Pennsylvania, and HERBERT FOX, M. D., Director of the Pepper Laboratory of Clinical Medicine, University of Pennsylvania. *Seventh Edition.* Octavo; 1111 pages; 509 illustrations, many in colors, and 15 colored plates. Philadelphia and London: W. B. SAUNDERS COMPANY, 1921.

The fact that this text-book has passed through seven editions and numerous reprintings in twenty-three years is evidence that it meets the desires of a large medical public. The book covers the entire field of general and special pathology and trenches also upon bacteriology and clinical pathology. To embrace all these subjects within the compass of 1111 pages requires extreme condensation, the sacrifice of much that is important, and the omission of much that is worth while and broadening in the study of pathology.

The chapters dealing with animal parasites, diseases of the blood vessels and diseases of the blood are good. The chapter on the endocrine organs is brought well up to date. The description of nephritis, in which the authors attempt to combine a clinical and a pathological classification, is not clear. In all other chapters an ultra-conservative desire to exclude all controversial matter has resulted in the omission or slighting of many new facts. To give a few instances: in the description of syphilitic lesions no mention of the finding of spirochetes in the sections is made; the description of endometrial diseases barely touches upon the long-accepted functional changes formerly classed as "endometritis"; the "fibroid heart" is resuscitated from the old text-books of gynecology.

The illustrations are fairly numerous. The original text figures and colored plates are good. The more numerous pictures derived from other sources vary greatly, some being well chosen and adequate, others, such as figures 53, 401 and 429, have no place in a modern text-book, having earned oblivion by long and faithful services during many by-gone years.

Diseases of the Intestines and Lower Alimentary Tract. By ANTHONY BASSLER, M.D., Professor of Gastro-Enterology, Fordham University Medical College and New York Polyclinic Medical School and Hospital; Visiting Physician, New York Polyclinic Hospital; Visiting Gastro-Enterologist, Peoples Hospital; Consulting Gastro-Enterologist, Stuyvesant Polyclinic, Beth-David and Christ's (N. J.) Hospitals. Octavo; 636 pages; 154 text engravings and 62 full-page half-tone plates. Philadelphia: F. A. DAVIS COMPANY, 1920.

This is a well written volume, the logical sequel of the author's book on "Diseases of the Stomach." The volume deals with a subject which is difficult to handle, insofar as the classification of intestinal diseases has always been one of much dispute and difference of opinion. The method of presentation chosen by the author is a favorable one in that he treats many of these diseases as a growth and thus the subject is made intelligible and comprehensible to the reader.

When we consider the extreme paucity of books in the English language on diseases of the intestine the addition of this interesting volume should be appreciated. The chapters on Anatomy and Physiology are full and clearly described. The section on Pathological Physiology and Pathological Chemistry, an understanding of which is so essential to an appreciation of intestinal function, is thorough and replete with facts and shows a close acquaintanceship with the literature, particualrly with much of the newer work. The chapters on Chronic Excessive Intestinal Toxemia follow closely the lines laid down in the previous work of this author. The different types of so-called intestinal intoxication are fully described from all aspects, particularly the bacteriological. The rigid pictures of the indolic and of the saccharo-butyric types seem overdrawn and it is very questionable whether the profession at large would accept the classification of clinical types as they are here described. It is still more doubtful whether the mass of the profession would subscribe to the vaccine therapy which the author here enthusiastically advises.

In dealing with the chapters on Lane kinks, Jackson membranes, ileal stases and ileo-cecal regurgitations the author expresses sound and well-balanced views, avoiding the extremes of those either too radical or too conservative. The surgical viewpoint of chronic appendicitis as a clinical entity as the "commonest abdominal affection" is accepted, a viewpoint which is being more and more questioned as time goes on. The chapters on Abdominal Diseases, including New Growths of the Intestines, is thorough. It is particularly commendable that the book is supplied with many radiographic pictures, the reproductions of which are clear and distinct and actually show what they are supposed to show.

All in all, the book deserves warm commendation as an interesting volume covering a complicated and poorly understood group of diseases.